The relationships between work-based noise over the adult life course and hearing in middle age

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INTRODUCTION

Between 1971 and 1991 in the US there has been an increase in prevalence of age-adjusted hearing loss (National Center for Health Statistics [NCHS] data in Lustig & Niparko 2002), attributed in part to increases in environmental noise. Over this period there has been substantial evidence of increase in non-work based noise. Industrial/occupational exposure to noise is still the major route through which noise impacts on the individual, but this may change in the near future.

Noise exposure is thought to explain around 25 % of variation in sensorineural hearing loss (SNHL) (Starck 1998; Pykko et al. 2000; Robinson 1970; ISO 1999 (1990)). However, individual susceptibility to noise has been reported to vary according to differences in ear musculature and size, pre-exposure to noise at lower levels, differences in vascular pathology, use of analgesics, serum cholesterol levels, blood pressure, smoking, genetic pre-disposition, pigmentation and age (Prasher 1998; Pykko et al. 2000) (though see Ward 1995 for an alternative view*). Clearly e*ffects of noise levels on adult hearing are larger at 4 kHz than at 1 kHz (Taylor et al. 1965; Robinson 1970) and this area is typically affected before other regions and so is often the major interest in any analysis – especially of younger populations.

To date, there is little evidence about the particular life stages at which the sensitivity of the individual to noise exposure is highest. This study aims to explore the age sensitivity in adults to noise, using ways of enhancing existing data from a British birth cohort; estimated exposure to noise based on membership of Occupational Unit Groups (OUGs) derived using the Registrar General's categories of Occupation groups; and self-reported exposure to work-based noise at different ages.

Data sources

In addition to a retrospective question of work- based noise exposure, the study uses data from a British birth cohort (Power & Elliott 2006) with pure tone audiometry measurements, both in childhood (ages 7,11,16 years) and adult pure tone audiometry was repeated at age 45 years. We used detailed information on social and demographic characteristics from which information on Occupational Unit Groups can be derived. Expert raters (four experienced audiologists and noise researchers) assessed each of the OUGs in respect of their noise level at each of four levels. We adjusted analysis for differences in childhood hearing loss, including any early social or genetic influences which work through this. This allowed us to:

a. quantify the effect of exposure to work-based noise at a number of adult ages (23, 33, 42 years) on hearing loss (1 kHz and 4 kHz) at age 45 years.
b. examine the adjusted effect of each exposure given exposures at other ages

c. provide estimates which adjust for social class at each age (note that the social class based noise ratings may also reflect other aspects of social class, including cultural correlates, which influence hearing loss, Ecob et al. 2008)
d. examine the effects of change in exposure to noise levels between adult ages
e. examine possible interactions between effects of noise exposure at different ages
f. examine the impact of these workplace-derived noise levels in relation to a retrospective question (at age 45 years) on exposure (duration) to work-based noise.

METHODS

Occupational Unit Groups (OUG) estimates of work based noise exposure

OUGs were rated corresponding to first job at age 23 years (in 1981) and to last or current job at ages 23, 32, 42 years (in 1981, 1991, 2000). Each OUG was given by a one line description and jobs within this were rated according to the percentage of people in these jobs with exposure, without hearing protection, at each of four ordinal categories, with descriptions in terms of a range of noise levels and the voice level needed to communicate at a distance of four feet. Figures 1 and 2 show the averaged values from the three best raters over major groups for 1980 and then for 1991/2000. The majority of major groups have low noise levels. Average noise levels in each of the major occupational groups in 1980 and 1990 are given in Figure 1 and Figure 2. High noise ratings are seen to be confined to few major groups.

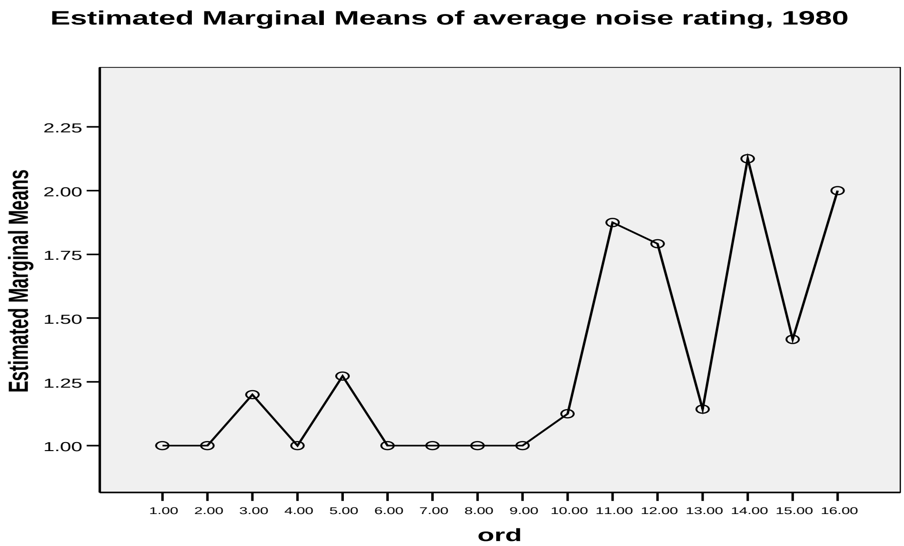

Figure 1: Average noise levels in major groups, 1981

Key: Major groups – 1981
1. Professional and related supporting management; senior national and local government managers
2. professional and related in education, welfare and health
3. literacy, artistic and sports
4. professional and related in science, engineering, technology and similar fields
5. managerial
6. clerical and related
7. selling
8. security and protective service
9. catering, cleaning, hairdressing and other personal services
10. farming, fishing and related

11. materials processing; making and repairing (excluding metal and electrical)
12. processing, making, repairing and related (metal and electrical)
13. painting, repetitive assembling, product inspecting, packaging and related
14. construction, mining and related not identified elsewhere
15. transport operating, materials moving and storing and related
16. miscellaneous

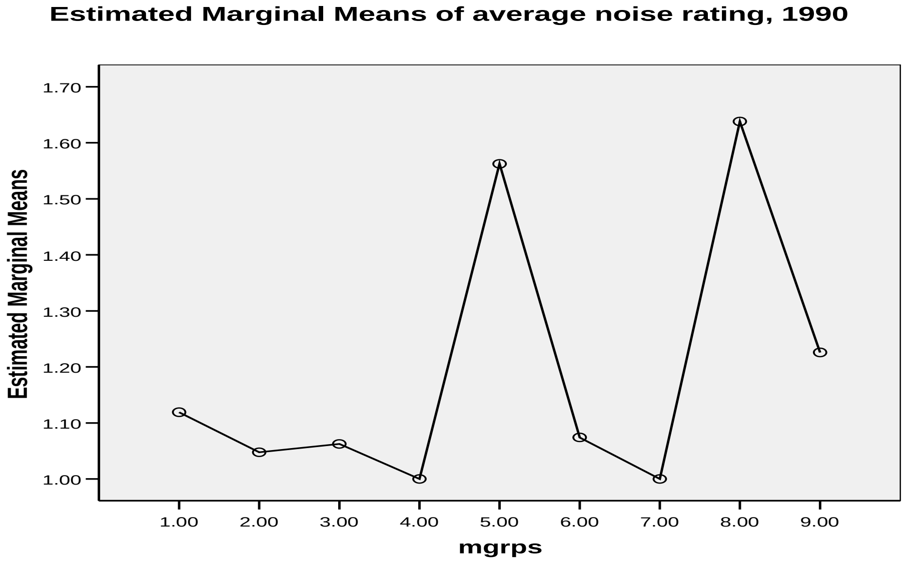

Figure 2: Average noise levels in major groups, 1991/2000

Key: Major groups 1991
1 Managers & administrators
2 Professional occupations
3 Associate professional & technical occupations
4 Clerical & secretarial occupations
5 Craft & related occupations
6 Personal & protective service occupations
7 Sales occupations
8 Plant & machine operatives
9 Other occupations

Duration of occupational noise was assessed at age 45 years by a self-completed, retrospective question: “Have you ever worked in a place that was so noisy that you had to shout to be heard?”. Questions were asked about age and duration.

Study sample

Participants were originally enrolled in the Perinatal Mortality Survey (PMS) of all those born in England, Scotland and Wales during one week in March 1958 (Power & Elliott 2006) and followed up throughout childhood and adulthood, most recently at 44-45 years. The Total Cohort Sample for this study was 18,558, out of which 12,069 participants at 44-45 years were still in contact with the study.

Pure tone audiometry at ages 7, 11 and 16 years and at 44-45 years

Pure tone audiometry was performed by air conduction in each ear, at frequencies 0.25 0.5, 1, 2, 4, 8 kHz, at three ages (7, 11, 16 years). The conditions in which these tests were carried were not closely standardized, so may not reflect true audiometric thresholds. Despite these reservations, the consistent relationships between adult and childhood hearing threshold level (HTL) at corresponding frequencies at each age (adjusted) is encouraging (Ecob, 2007). Pure tone audiometry by air conduction at frequencies 1 and 4 kHz at age 44-45 years was performed according to the British Society of Audiology recommended procedure (BSA 1981). The median HTL at both frequencies in this study at age 45 years is lower (better) than other recent studies in comparable unscreened populations in the UK (see National Study of Hearing; Davis 1995) and, indeed, the predictions for screened populations ('pure' prebyacusis) from ISO 7029 (1984).

Social class

Adult socio-economic position (referred to as current social class) is shown based on age at 23, 33, 42 years based on the participant's current or most recent occupation in the Registrar General's occupational groups: professional (I), managerial/technical (II), other non-manual (IIInm), skilled manual (IIIm), partly skilled (IV) and unskilled manual (V). For social class of origin those with no male head of household in childhood were grouped with class V.

Family history of hearing loss

This is measured by a question in biomedical wave (age 45 years). "Did any of your parents, children, brothers or sisters have great difficulty in hearing before age 55?"

Adjustment for possible conductive hearing loss in childhood

Two variables, at ages 7 & 11 years, provided proxy measures of possible present or past conductive hearing loss. No such variables were available at 16 years, though the prevalence above 11 years is known to be much lower (Haggard & Hughes 1991).

Adjustment for childhood hearing threshold level (HTL)

Childhood HTL was included in all statistical models as a combination of polynomial terms (up to cubic) in the 'base' frequency (that frequency in childhood most predictive of HTL in adulthood) and polynomial contrasts (up to quadratic) between the linear terms in this and other frequencies. At all childhood ages the 'base' frequency most predictive of HTL at 4 kHz in adulthood was found to be 4 kHz; for HTL at 1 kHz it was 2 kHz. Terms were selected for inclusion in the model on the basis of preliminary regressions of HTL at age 45 years on these childhood frequencies, selecting those with coefficients which were statistically significant at the 0.05 level. The final model includes seven terms over the three years in childhood HTL for 4 kHz outcome and five terms for 1 kHz outcome (Ecob 2007).

Models

Regression models were constructed to estimate effects of noise (as estimated both through the OUG measure at different ages and the retrospective measure), current social class, and childhood HTL on HTLs at age 45 years. Interactions between the effects of OUG based noise were examined at different ages. Multiple Imputation methods (Royston 2005) were used in all analyses using childhood HTL to impute missing values on all explanatory variables (details given in Ecob et al. 2008). Where there was valid data at 4 kHz at age 45 years, data was missing in childhood for 30 %, 26 %, and 29 % at 7, 11 16 years respectively. Only 44 % had complete HTL data at all childhood ages. All models were adjusted for each of the following variables: family history of hearing impairment, whether there was background noise at time of adult test, gender, whether migration within UK between birth and adulthood (standard region), region at birth and currently (age 45 years), proxies for conductive hearing loss in childhood (at 7, 11 years of age).

RESULTS

Table 1 shows OUG noise levels at the different ages. At all ages the proportions at each level are similar. The retrospective noise rating (Table 2) has a similar proportion at the lower end (no noise) but a higher proportion in the top category (>5 years noise exposure).

Table 1: OUG noise levels

		Age 23 (first) (1981)	Age 23 (current/last) (1981)	Age 33 (1991)	Age 42 (2000)
1	low	9323 (76.3 %)	7897 (78.5 %)	7606 (71.3 %)	7254 (75.3 %)
2	medium	2389 (20.0 %)	1855 (18.5 %)	2600 (24.4 %)	2011 (20.9 %)
3	high	503 (4.2 %)	303 (3.0 %)	468 (4.4 %)	369 (3.8 %)
total		12216 (100 %)	10055 (100 %)	10674 (100 %)	9634 (100 %)

Table 2: Retrospective noise levels (given valid 4 kHz threshold at age 45 years)

1	No noise	5749 (70.1 %)
2	Yes but less than 1 year	832 (10.1 %)
3	Yes and 1-5 years	643 (7.8 %)
4	Yes and >5 years	980 (12.0 %)
total		8204 (100 %)

Table 3 shows the stability of OUG noise levels over time. The substantial instability (69 %) in noise levels between first and current/last job in 1981 does not appear to be carried over to the instability between years, the stability over the last ten year period being higher (83 %) than the previous (74 %). Current/last job in 1981 shows stronger relations to 1991 and 2000 job than does the first job in 1981.

Table 3: % agreement between allocated noise levels to each individual over time

	%
1981 first v 1981 current/last	69
1981 first v 1991	72
1991 first v 2000	72
1981 current/last v 1991	74
1981 current/last v 2000	75
1991 current/last v 2000	83

Table 4 shows the marginal relation of hearing loss (1, 4 kHz) to the noise ratings, both OUG based and retrospective. Relationships are substantially higher at 4 kHz than at 1 kHz and show, for the high OUG noise ratings, some evidence of an increasing relationship with age. The relationship with high OUG is comparable with the retrospective high relationship for both frequencies, though the prevalence (see Table 2) is higher for the retrospective noise exposure for both frequencies.

Table 4: Marginal relation on raw scale of hearing loss (1,4 kHz) to noise ratings (in relation to low noise) [1]

a) 1 kHz	1981 first (age 23)	1981 current/last (age 23)	1991 (age 33)	2000 (age 42)
Low	-	-	-	-
Medium	0.65 (0.28, 1.02)	0.57 (0.19, 0.94)	0.59 (0.21, 0.97)	0.49 (0.13, 0.86)
high	0.63 (-0.15,1.41)	0.76 (0.04, 1.47)	1.53 (0.83, 2.23)	1.09 (0.34, 1.82)

b) 4 kHz	1981 first (age 23)	1981 current/last (age 23)	1991 (age 33)	2000 (age 42)
low	-	-	-	-
Medium	2.83 (2.06, 3.60)	2.53 (1.71, 3.35)	2.46 (1.73, 3.18)	2.19 (1.45, 2.94)
high	4.18 (2.13, 6.24)	3.64 (2.17, 5.12)	4.60 (3.03, 6.18)	5.05 (3.30, 6.79)

c) Retrospective noise rating in relation to hearing loss (4 kHz, 1 kHz)

Code	Description	1 kHz	4 kHz
1	No noise	-	-
2	Yes but less than 1 year	-0.47 (-0.90, -0.05)	0.86 (-0.06,1.78)
3	Yes and 1-5 years	0.76 (0.27, 1.25)	2.80 (1.73, 3.87)
4	Yes and >5 years	0.78 (0.37, 1.20)	4.10 (3.16, 5.03)

We applied the models to look at the relation of OUG noise to hearing loss (4 kHz and 1 kHz) at age 23, 33 and 42 years and found that:

- When we look at the marginal relationship and mutually/non-retrospective relationship, the relation of OUG noise appears to be stronger at earlier ages for 4 kHz and 1 kHz
- If we additionally adjust for social class at each age we find the same pattern
- If we further mutually adjust to include retrospective self-ratings of noise exposure we find the same pattern
- The 1981 OUG effect at 4 kHz for age 23 years is stronger than the OUG effect for 1991 and 2000.

This is confirmed by re-analyzing the data to show directly the effects of changes in noise ratings between the years (Table 5). The 4 kHz hearing loss is strongly related to the noise level in 1981, with a 4.1 dB (CI 2.8, 5.4) difference in hearing loss occurring between the low and medium/high ratings. An increase in noise rating from 1981 to 1991 (ages 23, 33 years) from low to medium/high is associated with an increase in hearing loss (1.5 dB, CI 0.6, 2.5) and, correspondingly a decrease from low to medium/high is associated with an decrease in hearing loss (-2.7 dB, CI -3.8, -1.5).

[1] from log model, transformed back

Table 5: Adjusted relationship of hearing loss to noise exposure ratings in 1981 and to and changes between 1981 and 1991 and between 1991 and 2000 (estimates (with CI))[234]

Noise rating	1 kHz	4 kHz	N
1981 (yes)	0.36 (-0.26,0.98)	*4.10 (2.78, 5.42)*	
1991 yes given 1981 no	0.12 (-0.37,0.61)	*1.52 (0.58,2.45)*	1141
1991 no given 1981 yes	-0.14(-0.74, 0.45)	*-2.68(-3.84, -1.52)*	471
2000 yes given 1991 no	0.32 (-0.31, 0.94)	0.76 (-0.38, 1.90)	460
2000 no given 1991 yes	-0.08 (-0.44, 0.61)	-0.83 (-1.78,0.12)	730

Table 6 shows, for 4 kHz only, the effect of this overall measure, in relation to no noise. In models without control for childhood hearing loss the effects of the overall OUG measure are larger than the retrospective measure but with control for childhood hearing loss, and especially social class, the effects are comparable.

Table 6: OUG ratings amalgamated over time

model		**4 kHz**
A (overall oug only)	Oug-medium	3.01 (2.48, 3.54)
	Oug-high	6.52 (5.69, 7.36)
B (adjusted for retrospective, with retrospective)	Oug-medium	2.41 (1.86,2.95)
	Oug-high	5.20 (4.34, 6.06)
	retrospective-low	1.05 (0.32, 1.78)
	retrospective-medium	1.89 (1.03, 2.74)
	retrospective-high	2.95 (2.17, 3.72)
C (B + social class only)	Oug-medium	2.11 (1.57, 2.65)
	Oug-high	4.65 (3.82, 5.49)
	retrospective-low	0.98 (0.29, 1.68)
	retrospective-medium	1.68 (0.88, 2.48)
	retrospective-high	2.70 (1.97, 3.42)
D (B + childhood hearing loss only)	Oug-medium	1.48 (0.75, 2.21)
	Oug-high	3.45 (2.31, 4.59)
	retrospective-low	0.63 (-0.23, 1.49)
	retrospective-medium	1.89 (0.85, 2.92)
	retrospective-high	3.00 (2.01, 3.99)
E (B + childhood hearing loss + social class)	Oug-medium	0.93 (0.25, 1.61)
	Oug-high	2.42 (1.39, 3.47)
	retrospective-low	0.50 (-0.29, 1.29)
	retrospective-medium	1.47 (0.53, 2.41)
	retrospective-high	2.52 (1.62, 3.41)

[2] social class at ages 23, 33, 42 years are adjusted for
[3] from log model, transformed back
[4] italic =statistically significant at 0.05 level

DISCUSSION

We have shown how longitudinal data sets can be enhanced to give age related estimates of noise exposure through OUGs rated by experts for average noise levels on a probabilistic basis.

We have noted also the tendency (at 4 kHz) for the ratings at earlier adult ages to more strongly related to subsequent hearing loss. This is despite the likelihood of a greater variability in noise exposure over time at younger ages. Could this apparent increase in the effect of noise at earlier occasions be due to artifacts? The likely effect of the difference in OUG coding schemes between 1981 and 1991 is difficult to assess but is likely, if anything, to bias the results towards greater effects at the later periods. It is possible that a greater exposure to noise in 1980 was due to differential hearing protection over time (note that the ratings of noise for the OUGs were made on the assumption of no hearing protection throughout). Legal requirements meant that hearing protection increased over this period in the UK, so there may have been greater actual exposure in the early adult years in this cohort; in the later adult years protection may have improved.

We now raise a number of further issues

1. How comparable are the different estimates of noise exposure? In this study we have used a number of ways of estimating noise exposure and found reasonable comparability. Of course there are caveats. The OUG estimates are contemporary (though at one point in time only) and form averages over all those in a particular OUG (through probabilistic coding). They also pick up effects of social classification of individuals which may proxy for further aspects of noise exposure apart from work based noise, perhaps especially at younger adult ages. These are of intensity only, though duration can be estimated crudely though averaging of the ratings, possibly recoded, at different occasions (1981, 1991, 2000). In contrast the retrospective noise exposure is of duration not intensity, is prone to the biases (e.g. telescoping) associated with retrospective reports over a long period of time (up to 30 years). In the final model (E) (Table 5), in which social class is adjusted for, the effects of the retrospective noise dominates all the OUG estimates, although less strongly for those for 1981. However it is likely that this model underestimates the effects of noise from OUGs and that the results adjusting for social class are more appropriate because they eliminate some of the real differences (those between social groups) in noise levels (see Ecob et al. 2008).

2. The absence of any evidence of interaction between effects of OUG based noise at different ages provides some evidence against theories about the protective effect of noise at early adult ages.

3. This enhancement to this data set increases the potential of using it in the study of the relation to the effects of noise on other health outcomes (malaise etc) and of the combined effects of noise with a range of other characteristics (anthropological, social) on hearing loss. Such enhancements can be applied to any data set with hearing measures, longitudinal or otherwise, and information on type and nature of work undertaken. Large studies are very costly and time-consuming; enhancing data from existing studies is an important way of expanding our knowledge on noise exposure and hearing loss.

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