

Children's perception of their acoustic environment

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Children's perception of their acoustic environment at school and at home

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ABSTRACT

This paper describes the results of a large-scale questionnaire survey that ascertained children's perceptions of their noise environment and the relationships of the children's perceptions to objective measures of noise. Precision, specificity and consistency of responding was established through the use of convergent measures. Two thousand and thirty-six children completed a questionnaire designed to tap a) their ability to discriminate different classroom listening conditions, b) the noise sources heard at home and at school and c) their annoyance by these noise sources. Teachers completed a questionnaire about the classroom noise sources. Children were able to discriminate between situations with varying amounts and types of noise. A hierarchy of annoying sound sources for the children was established. External $L_{\max} - L_{A\max}$ levels are a significant factor in reported annoyance whereas external L_{A90} and L_{A99} levels are a significant factor in determining whether or not children hear sound sources. Objective noise measures (L_{A90} and L_{A99}) accounted for 45% of the variance in children's reporting of sounds in their school environment.

The current study demonstrates that children can be sensitive judges of their noise environments and that the impact of different aspects of noise needs to be considered. Future work will need to specify the bases for the developmental changes and the physical and location factors that determine the school effects.

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I. INTRODUCTION

Primary school children are particularly vulnerable to extraneous noise sources (Shield and Dockrell, 2003), yet are likely to experience high levels of noise in classrooms (Blake & Busby, 1994). It has been shown that a child's understanding of speech in noise and reverberation does not reach an adult level until late teenage years. Before this time, the younger the child the greater the detrimental effect of noise and reverberation (Werner & Boike, 2001; Stelmachowitz *et al.*, 2000; Soli & Sullivan, 1997; Johnson, 2000) with children under about 13 years of age being particularly susceptible. Primary school children require more favourable signal to noise ratios than adults to achieve comparable levels of accuracy in understanding of speech (Fallon, Trehub & Schneider, 2000). Classrooms tend to have poor acoustics, children are subject to high levels of background noise (Shield *et al.*, 2000; Berg, Blair & Benson, 1996) and, due to long reverberation times, much speech will be distorted and not easy to understand (Airey, 1998). Moreover younger children are more distractible than older children and adults (Gumenyuk *et al.*, 2001). This potentially exacerbates the effects of environmental noise by increasing off-task behaviour (Blatchford, Edmonds & Martin, 2003) or indiscriminate tuning out of all stimuli resulting in generalised poor attention (Stansfeld *et al.*, 2000). Research over the last 30 years has contributed to understanding of the effects of noise on children's learning and motivation (Evans & Lapore, 1993; Shield & Dockrell, 2003). Yet, little is known about children's perceptions of their school acoustic environments. This paper describes a large scale questionnaire survey of children that was carried out to ascertain children's perceptions of their noise environment and how the children's perceptions related to objective measures of noise.

Early studies have indicated that children are exposed to high levels of noise throughout the day. Dosimeters used with children over extended periods indicate that

equivalent sound pressure levels of about 70 dB(A) are common (Roche *et al.*, 1978; Schori & McGatha, 1978, cited in Evans, 1990). More recently noise measurement made at schools near airports (Haines, Stansfeld, Job, Berglund & Head, 2001; also 2002 paper) and near major traffic arterials have confirmed that children in these situations are exposed to high levels of environmental noise and, in some circumstances, report high levels of annoyance from the specific sound sources studied (Cohen *et al.*, 1981). Furthermore, children who ~~lived- live~~ in noisier areas ~~rated- rate~~ their neighbourhoods as significantly more noisy (Evans *et al.*, 2001). Thus, there is increasing evidence about children's exposure to noise and some preliminary evidence that children may be able to judge their levels of noise exposure. However, there are difficulties in generalising to school children at large from these studies. Firstly, interpretation of the data from dosimeters with children is complex. A total day exposure will not indicate what a typical school exposure is, since it will include the playground, watching TV, listening to music and so forth. Secondly, the interpretation of dosimeter data from younger children is confounded by the fact that the children themselves make a lot of noise resulting in unreliable measurements (Shield & Jeffery, 2001). Finally, it is not clear to what extent data that are collected from high noise spots created by single sound sources, such as planes or trains, will be comparable to other school contexts, where children will hear a variety of sound sources at different levels. Thus, it is important to establish children's perception of and annoyance by a range of sound sources in typical classroom environments.

The most widespread and well documented subjective response to noise is annoyance, despite the fact that there are major differences in the ways in which noise annoyance is conceptualised (Guski, Felscher-Suhr & Schuemer, 1998). A number of studies with adults have confirmed a dose response relationship between levels of specific transportation noises and levels of annoyance reported (Fidell, Bouer & Schultz, 1991;

Miedema & Vos, 1998; Miedema & Oudshoorn, 2001). Accurate comparisons between surveys are complicated by differences in annoyance scales, noise estimation procedures and study conditions (Fields, de Jong, Brown...1997; Fields.... 2001). Nonetheless, adult measures of noise annoyance do show reasonably high correlations with objective noise measures (0.3-0.5) with correlations for group data being higher (approx. = 0.89) (see Job, 1988 for a discussion of these issues). Perfect correlations would never be expected since acoustic parameters are only one of a complex set of variables involved in levels of noise annoyance (Guski, Felscher-Suhr & Schuemer, 1998). A range of other factors will impact on an individual's judgement including relative background noise levels, reaction measurements, age, education, sex, health of the individual and task engaged in when making the judgement (Evans & Tafalla, 1987; Job, 1988). Having reviewed the relevant literature Job highlights the fact that attitude to noise source is "a genuine modifying variable" (1988:1000). Infrequently occurring events may play a larger role than might be expected. This may reflect the contrast between loud noise and ambient background sound. Despite the continuing interest in adults' levels of annoyance and the increasing sophistication of the interpretations of individuals' ratings, children's annoyance with noise sources appears to be an under researched area, although there has been some limited work in recent years (~~but see~~ Haines & Stansfeld, 2000; Lercher, Brauchle, Kofler, Widmann & Meis, 2000). Data from studies of children's responses to aircraft noise indicates that the children were consistently found to be annoyed by chronic aircraft noise exposure (Evans *et al.*, 1995; Haines *et al.*, 2001a; 2001b; 2001c). In their study of the effect of high levels of aircraft noise Haines *et al.* (2001 b) have demonstrated that annoyance levels due to aircraft noise were significantly higher, among children in high aircraft noise schools compared with low aircraft noise schools. This result applied to aircraft noise annoyance both at school and at home. In contrast, levels of annoyance to

road traffic noise both at school and at home in the Haines *et al.* (2001b) study did not differ significantly across high and low noise schools. While providing initial data which indicate that children's levels of annoyance are related to specific sound sources these data fail to capture the variety of noise sources that may impact on children in their learning environment. As yet it has not been established whether children are annoyed by general classroom noise and whether levels of annoyance are related to classroom noise levels.

Capturing an accurate reflection of annoyance and levels of annoyance is complex (Diamond & Rice, 1987; Job, 1988). The noise environment comprises more than one source of noise so research needs to identify the range of noises that are typical for children. Not all sources of noise will be equally annoying and, as with adults, it may not be the level of the noise that is the key feature of annoyance for children (Guski, Felscher-Suhr & Schuemer, 1998; Haines & Stansfeld, 2000; Lercher *et al.*, 2000). Different sources need to be considered individually and in combination to assess relative levels of annoyance. Measuring annoyance is premised on the fact that particular sound sources are audible. Thus, for any particular child it is necessary to establish that particular sound sources are heard before it can be determined whether they are annoying. Validity of such judgement would be enhanced if: 1) it could be shown that children can discriminate across classroom conditions in terms of teacher and peer audibility; and 2) teachers' perceptions of sound sources were similar to those of the children in their class. Thus, in addition to the children's ability to judge the presence and annoyance of a sound source convergent evidence from teachers' ratings and children's ability to discriminate across listening conditions is required.

The present study fills a gap in the noise literature by examining children's perceptions of their noise environment across a representative sample of schools in [a](#) large urban

conurbation and relates these perceptions to objective measures of noise levels in their schools. Questionnaire surveys were used to:

1. Assess children's awareness of environmental noise sources at home and at school and to consider the extent to which children are annoyed by these sources;
2. Evaluate the extent to which the child's development stage impacts on perceptions of noise and relative annoyance;
3. Document children's ability to differentiate good and poor listening situations in classrooms.

Objective measures of noise levels were used to establish noise levels and sound sources in the children's classrooms. Research with children has often been compromised by a failure to consider the child's perspective on the variables under consideration (Dockrell, Lindsay & Lewis, 2000). This has often led to underestimation of children's abilities and understandings (Dockrell *et al.*, 2000) and a failure to identify the range of factors that may impact on successful school performance. To avoid these methodological failings an important first step in evaluating children's noise environments is to gain their perceptions of the noises that they hear and the noises that annoy them. Thus, the questionnaire used in the current study was based on the results of in-depth interviews with children and their reports of the sound sources in their environment and the classroom listening conditions that they experienced. These data were supplemented by interviews with their teachers. It was necessary to construct a questionnaire that would be understood by young children without placing too many demands on their language, memorial or non-verbal skills (Smedslund, 1969). Pictures were used to contextualise questions and when children were reporting whether they heard sounds or were annoyed by sounds dichotomous responses were required. To construct a valid and reliable tool two phases of

pilot studies were carried out prior to the main study. The use of convergent measures of the children's awareness and reactions to noise will enhance the conclusions that can be derived from the current data set.

II. PARTICIPANTS

The sample in the main study consisted of primary schools in one area in London. The area was chosen to reflect the typical distribution of socio-economic status among London primary schools and a range of primary school environments. The borough was representative of Greater London for location and for demographic qualities (subject to the exclusion of west London boroughs exposed to high levels of ~~to~~-aircraft noise). The estimated borough adult population was 216,800 with an average household size of 2.4 and an unemployment rate of 9.4%. The average teacher pupil ratio in the primary schools was 1:22.4 and children with special educational needs represented less than 2.4% of the primary school population. Over 50% of the population were white, with Black Afro Caribbean's representing the largest minority ethnic group (10%). The assessments of the pupils' attainments within the area fell within the normal distribution for all English Education Authorities (DfES, 1999). The two age groups identified as participants reflected the end points of infant and junior school. National tests in England provide comparative performance of reading and numeracy attainments. Thus, the study was conducted among Year 2 (6 to 7 year olds) and Year 6 (10 to 11 year olds) children. Overall, the area-borough had, at the time of the study, 54 primary schools. The study was conducted in 43 schools. The number of the children that participated in the study was two thousand and thirty-six (2036). From those, 885 (43.5%) were in Year 2 and 1151 (56.5%) were in Year 6. The sample consisted of 1041 (51.1%) boys and 995 (48.9%) girls. The

age distribution of the sample was: six years, 8.1%; seven years, 35.9%; 10 years, 14.2%; 11 years, 41.8%.

Fifty-one teachers in 34 schools completed the questionnaires (12 in Year 2 and 39 in Year 6). Eleven were male and 40 female. Over half the sample (59%) had more than five years experience, with 20 per cent having more than 20 years experience. For those who reported their age (N=39) there was a mean of 37 years (range 26-55).

III. MATERIALS

A. Questionnaire Design

1. Phase 1: Child interviews

Semi-structured interview methods were employed with Year 2 and Year 6 children and their teachers. This phase took place in one primary school in the UK. Thirty children and their teachers were interviewed. The objectives were to identify the different noise sources that children were aware of and to determine types of noise they might be exposed to and annoyed by both at school and at home. Interviews with teachers explored their perception of noise in the school environment and children's performance in noisy situations. In the interviews the research team used only the word 'sound' deliberately avoiding the term 'noise' so as to reduce the possibility of bias in the responses. However, the children consistently used the words 'noise' and 'sound' interchangeably.

The noise sources that emerged from the analysis of the interviews via transcription were categorised as follows:

- Noise made by people;
- Transportation noise (e.g. cars, buses, aeroplanes, etc.);
- Entertainment noise (e.g. stereo, musical instruments, TV, etc.);
- Noise from nature (e.g. trees, birds, dogs, cats, etc.);

- Noise from machines (e.g. telephone, etc.).

The above information served as the basis to develop a child questionnaire and a teacher questionnaire that were used in the pilot study.

2. Phase 2: Pilot study

The questionnaires were administered to a total of 84 pupils in Year 2 ($n = 39$) and Year 6 ($n = 45$) classes and their teachers. As a result of feedback about ambiguity in the certain questions changes were made in the pupil questionnaire. A confirmatory sub-sample of 6 schools was used for the trial study. The sample consisted of 343 pupils, 164 boys (47.8 %) and 179 girls (52.2 %), from six Year 2 classes (131 pupils, mean age 6;7) and eight Year 6 classes (212 pupils, mean age 10;7). Debriefing with the participants indicated that the questionnaire was developmentally appropriate and captured the children's views. Analysis indicated that children were differentiating between home and school.

B. Pupil Questionnaire - final version

The ten-page questionnaire was divided into three sections (the questionnaire can be requested from the authors). Four versions of the questionnaire, varying the order of questions, were developed for randomisation purposes. Section A examined the sound sources children were exposed to in their environment both at home and at school. In Section A children were asked for each sound: a) whether they heard the sound source in their classroom ('hear' questions); and b) if they heard the sound source whether they were annoyed by it ('annoy' questions). Questions were accompanied by a graphic representation of the noise source followed by a tick box for the children to record their responses. The same questions were repeated for 'hear' and 'annoy' at home. Hear and annoy questions

were presented as dichotomous yes-no answers to aid completion by the younger children. Annoy questions were only completed when children reported hearing a particular noise source.

Section B examined listening situations across nine classroom activities and contexts. These situations were chosen from the pilot interviews with children and previous work (Arnold & Canning, 1999). Section B used a five point Likert scale transformed into a smiley faces rating scale based on that of Arnold and Canning (1999). Children rated how well they hear what the teacher is saying in the 8 different classroom situations and how well they hear their peers speaking in the classroom. The anchor ends of the scale were 'very well' and 'not at all'.

The children were asked how well they could hear the teacher in the following classroom situations:

- when the child could not see the teacher's face;
- whilst the teacher was moving around the classroom;
- when the children were working in groups;
- when there was no noise at all;
- when children were making noise outside the classroom;
- when there was no noise from outside the classroom;
- during exam conditions;
- when children were outside during physical education lessons.

Children were also asked if they could hear a classmate responding to a teacher's question.

Section C collected demographic information. Both Section A and Section B were preceded by series of trial items to familiarise the children with the demands of the questionnaire and to allow for any problems or questions raised by the children ~~raised~~ to be addressed.

A number of steps were taken to ensure the validity of the questionnaire and the reliability of the children's results. The validity was established by ensuring ~~the~~ that the noise sources presented reflected those reported by children in the open-ended pilot interviews, the published literature and pilot data collected in inner London locations. Differentiation between noise sources and home and school was regarded as a key indication of validity.

Children's responses to rating their ability to hear the teacher ~~had~~ have been shown to be reliable by Arnold and Canning (1999). The 'hear' and 'annoy' questions ~~had been~~ were extensively piloted and shown to be understood by children of this age range and to produce high levels of agreement with interviews. In addition, following Haines and Stansfeld (2000), children were assured that there were no right or wrong answers, and the questions were read to the younger children. Four different versions of the questionnaire were used to prevent order effects, and different versions were used within each class. As indicated in the participants' section the sample was representative ~~of children~~ of inner city children. Reliability of the children's responses was further ~~In addition reliability was~~ established by comparison with teacher's ratings of the same items.

C. Teacher Questionnaire

To complement the children's data a questionnaire with open-ended and closed questions was developed for the teachers to determine: a) the environmental noise(s) teachers hear in the classroom; b) the perceived impact that noise has on their pupils' performance; and c) their perception of noise as related to classroom and school activities. The five-page questionnaire consisted of four parts. The sound sources included in the

teacher questionnaire were identical to the ones in the children's questionnaire to allow for comparison with the children's responses.

D. Procedure

The questionnaires were administered to the Year 2 and Year 6 classes during the school day. At the beginning of each session, children were briefly introduced to the project. This introduction was followed by a thorough description of the questionnaire and an explanation of the way children should record their answers. Children were told that they could work at their own pace, as the questionnaire was not time-limited. In addition, the administrators assured participants about confidentiality. Children were allowed and encouraged to ask questions at any time during the presentation and were assured that there were no right or wrong answers. They were told that their own views were important. Children were keen to express their opinion.

Year 6 children completed the questionnaire as a class while Year 2 children were taken in smaller groups with a maximum size of ten children. Once the task was described each question was read aloud to the children and when the whole group was finished the next question was read aloud. The questionnaire completion time for the Year 6 children was 20 minutes and for the Year 2 pupils 35 minutes.

The teacher questionnaire was given to the teachers of all the classes used in the pupil survey. It took approximately 20 minutes to answer all the questions. The Year 6 teachers completed the questionnaire at the same time as their pupils while the Year 2 teachers completed the questionnaire during break-time.

IV. RESULTS

The results are presented in 6 sections. The first section provides objective measures of the levels of environmental noise that the children are exposed to at their schools. The second section describes the children's ability to differentiate across various listening contexts in their classrooms. The relationship between the children's scores and the objective measures of environmental noise are outlined in the next section. The subsequent section describes the noise sources heard in classrooms and homes and whether children are annoyed by these sources. The fifth section considers the relationships between children's reported hearing and annoyance levels and the objective noise measurements, the final section compares the children's and the teachers' views.

A. Exposure to environmental noise

An external noise survey of 53 schools in the area including 43 schools in the questionnaire survey was carried out ([Shield & Dockrell, in press](#)). Five minute samples of noise were measured outside each school using a Bruel and Kjaer hand held sound level meter, type 2236. For security reasons measurements were made off the school premises ([Shield & Dockrell, submitted](#)), where possible outside the noisiest façade, at the curbside of the nearest road. In many cases the measurement position was at approximately 4 m from the school façade. For consistency measurements at other positions were corrected to give the corresponding level 4 m from the façade.

The 5 minute measurement period was chosen to be typical of the school day. For this reason rush hours, times when children were arriving at or being collected from school, and when children were outside in the school playground were avoided.

The means and standard deviations of the measured parameters $L_{Aeq,5min}$, $L_{A10,5min}$, $L_{A90,5min}$, $L_{Amax,5min}$, are shown in Table I.

INSERT TABLE I HERE

In addition to noise levels, during the 5 minute measurement period the noise sources heard were noted. Percentages of recorded instances of the most frequently heard external noise sources occurring during the survey are presented in Figure 1. The most commonly occurring source of noise was road traffic, principally cars. Sirens were heard at surprisingly few schools, although they are commonly regarded as a regular feature of the London noise environment.

INSERT FIGURE 1 HERE

B. Children's ability to differentiate between listening context

Children's scores of their ability to hear the teacher (Section B of the questionnaire) in the different contexts are reported in Table II. The maximum possible rating was 5 and the minimum rating 1. As the table shows the full scale was used by the children. These data are not normally distributed so non-parametric statistical analysis also was carried out. Children's reported ability to hear the teacher varied significantly across situations ($\chi^2 = 4426, p < .001$) with 'no noise outside the classroom' and 'doing a test' reported as the best listening conditions and 'noise being made outside' by other children the worst. Comparisons were made between the ratings of the Year 2 and Year 6 children as shown in Table II. Younger children generally reported that hearing the teacher was significantly more difficult. This was true in 6 of the 9 situations assessed: when the teacher 'was talking and moving' ($U = 394579.5, p < .001$); 'no noise outside' ($U = 394382, p < .001$); 'doing a test' ($U = 355254.5, p < .001$); 'PE in the playground' ($U = 461915.5, p < .001$); 'no noise at all' ($U = 409882.5, p < .001$); and 'classmate speaking' ($U = 418452, p < .05$).

In contrast, relative to the younger children the older children reported significantly greater difficulty when they could not 'see the teacher's face' ($U = 392595.5$, $p < .001$) and when 'children were making noise outside classroom' ($U = 423164$, $p < .001$). There were no group differences in reported hearing acuity when children were working in groups ($U = 490863.5$, ns). These results indicate that primary school children are able to judge situations where they have difficulty hearing the teacher, and that younger children report relatively greater difficulty than older children. Children are thus able to discriminate between situations with varying amounts and types of noise.

INSERT TABLE II HERE

C. Comparison of children's listening scores with external noise measurements

The relationships between external noise levels and children's hearing across situations was assessed by a series of correlations. There were no significant relationships between the objective external noise measures and children's reported ability to hear in 8 of the 9 conditions assessed. However, reported ease of hearing the teacher in the classroom in the 'no noise outside' ~~-(from children)~~ condition was related to external noise measurements. The higher the objective noise levels the less likely the children were to report being able to hear the teacher (for L_{Aeq} ~~we found~~ $r = .365$, $p < .05$, for L_{Amax} ~~we found~~ $r = .338$, $p < .05$, for L_{A99} ~~we found~~ $r = .330$, $p < .05$, for L_{A90} ~~we found~~ $r = .376$, $p < .05$, for L_{A10} ~~we found~~ $r = .345$, $p < .05$). All aspects of the sound, ambient (L_{Aeq}), background (L_{A90}) and underlying ~~noise-(L_{A90} - L_{A99})~~ noise levels, plus, and maximum levels due to individual events (L_{Amax}) were related to the children's ability to hear the teacher. These variables account for, on average, 11% of the variance in the children's

responses, with L_{A90} accounting for the highest proportion of variance (14%). Thus, external school levels did affect the children's reported relative ease of hearing their teacher when other confounding noise sources such as other children in the classroom or teaching contexts were not relevant.

D. Environmental noises heard by children at home and at school

The following analyses consider children's awareness of particular forms of environmental noise at home and at school, and relative annoyance caused by different sources. Children reported hearing a wide range of environmental ~~sound-noise~~ sources both at home and school. The percentages of children reporting hearing the different sources at home and at school ~~is-are~~ shown in Figure 3. As the figure shows, different patterns emerge for reported hearing in class and at home. A mean score for hearing each sound source was computed for each class and this was compared with their class mean hearing score for hearing at home. Significant differences emerged for all home-school pairs apart from hearing music ($t = .572$, $df = 50$, ns) with children significantly more likely to report hearing sounds at home for animals ($t = -20.03$, $df = 50$, $p < .001$); phone ($t = -14.21$, $df = 50$, $p < .001$); bus ($t = -3.38$, $df = 50$, $p < .001$); TV ($t = -25.4$, $df = 50$, $p < .001$); motorbike ($t = -8.33$, $df = 50$, $p < .001$); car ($t = -6.465$, $df = 50$, $p < .001$); train ($t = -2.98$, $df = 50$, $p < .01$); trees ($t = -5.96$, $df = 50$, $p < .001$); helicopters ($t = -10.52$, $df = 50$, $p < .001$); sirens ($t = -10.18$, $df = 50$, $p < .001$); stereos ($t = -23.45$, $df = 50$, $p < .001$); planes ($t = -9.89$, $df = 50$, $p < .001$); lorries ($t = -5.18$, $df = 50$, $p < .001$). To some extent these results reflect the typical sound sources that occur in homes such as stereos and TVs. However, in addition, it is also likely to reflect a lack of precision in the question asked and the concept of 'home'. Home could include living room, kitchen, bedroom or garden thus allowing much more variation in the child's interpretation of the questions, whereas

the school question referred to classrooms only. ~~Nevertheless, the fact that children~~ ~~The task that children~~ discriminated between these two ~~environments~~ ~~context~~ provides further evidence of the reliability of the measure.

INSERT FIGURE 3 HERE

The percentages of children's relative hear and annoyance scores in the classroom by year group are reported in Table III. Once the children's reporting of hearing a sound source is controlled the annoyance levels are similar between home and school for all items. Moreover, ratings of annoyance at home and at school are highly correlated: phone ($r = .331, p < .05$); bus ($r = .409, p < .01$); TV ($r = .445, p < .001$); motorbike ($r = .566, p < .001$); car ($r = .566, p < .001$); train ($r = .524, p < .001$); trees ($r = .676, p < .001$); helicopters ($r = .344, p < .05$); sirens ($r = .534, p < .001$); stereos ($r = .499, p < .001$); planes ($r = .646, p < .001$); lorries ($r = .421, p < .001$); except for animals ($r = .23, ns$), and music ($r = .008, ns$). Thus, it would appear that for the children the majority of sound sources assessed in this questionnaire are annoying independent of the context in which they are heard.

INSERT TABLE III AND IV HERE

Tables III and IV show year group variation in ~~hear~~ing and annoyance and school variation in ~~hear~~ing and annoyance.

In general, older children were more likely to report hearing a sound source when responding about classroom and home listening conditions. However, age only accounted for a small proportion of the variance, on average less than 1% of the variance. In contrast, younger children tended to report greater annoyance but again little variance was

accounted for by age. Apart from trains and motorbikes the younger children report being more annoyed by the external noise sources that they hear. In contrast older children seem to be more aware of external noise sources.

In contrast to the developmental patterns reporting of hearing and annoyance varied by school for all sound sources. To conserve space the means of the 51 schools are not presented but Chi-square, significance levels and variance accounted for by these data are presented in Table IV. There were significant differences across schools in the sound sources reported. In all cases greater than 4% of variance was accounted for by school location and for train and phone noise school location accounted for 26% of the variance. Thus there was a clear indication that school and class factors played a significant part in whether children were reporting the occurrence of particular types of environmental noise.

E. The relationship between objective noise measures and pupils' perceptions

The data did not allow comparison of reports of hearing individual sound sources and actual occurrences, since a maximum score of one occurred for the sources observed during the acoustic survey at each school. However, relative rankings of children's observations could be established and are presented in Table V. As the table shows apart from cars, which are ranked most frequently by children and observed most often, there is little agreement. Of particular significance is the high ranking of sirens by children but the low ranking from the sound source observations. These data indicate that the relationships between the observations of individual sounds and children's ratings do not correspond. However, it is possible that measured noise parameters may provide a more valid index for evaluating the children's judgements.

INSERT TABLE V HERE

To establish whether children's perceptions of noise and annoyance related to the objective noise measures it was necessary to compute a single 'hearing²_score' and a single 'annoyance score' for each school. Children's reports of hearing an environmental sound and their relative annoyance were combined to create a '*school hearing score*' and a '*school annoy score*'. Given different numbers per classroom and different base rates these were computed as proportion scores. Three different scores were computed: '*school hearing score*' which was the average of the class reporting of all 14 different sound sources; '*school annoy score*' which was the average annoyance reported for the whole class and a '*child annoy score*' which was the average annoyance score for children who reported hearing a particular sound source. The scores are defined as shown in Box 1. Child annoy scores are always greater than school annoy scores since they are over a smaller base (only those children who report hearing the sound source). Overall the mean '*school hearing score*' was .46 (range .31-.59), the mean '*child annoy score*' .46 (range .21-.88) and the mean '*school annoy score*' was .22 (range .09-.39). While '*school hearing score*' was significantly associated with '*school annoy score*' ($r = .615, p < .01, n = 51$) it was not related to '*child annoy score*' ($r = .089, n = 51$). Thus the average reporting of hearing sound sources was related to the overall annoyance levels expressed by a class but not individual reported annoyance levels.

INSERT BOX 1 HERE

'*School hearing score*' was related to L_{A99} ($r = .52, p < .01, n = 38$), and L_{A90} ($r = .433, p < .01, n = 38$). However, '*school annoy score*' was related to L_{Amax} ($r = .326, p < .05, N = 38$), L_{Aeq} ($r = .359, p < .05, n = 38$) and L_{A90} ($r = .35, p < .01, n = 38$), whereas

'*child annoy score*' was only related to L_{Amax} ($r = .333$, $p < .01$, $n = 38$). Thus, children in classrooms where schools had higher external background noise levels reported hearing, on average, higher percentages of external sound sources. In contrast, ambient and maximum noise levels were a significant factor in reporting levels of annoyance but not levels of hearing sound sources.

Multiple regression analyses were conducted to investigate the combined and unique contribution of noise levels on both *annoy* measures and '*school hearing score*'. These analyses only included those noise variables that were significantly correlated with the target measure. No significant model emerged for '*school annoy score*' whereas for '*child annoy score*' a significant model emerged ($F_{1,37} = 4.485$, $p < .05$, Adjusted R square .086). The model accounted for little of the variance in children's responses. In contrast, a highly significant model emerged for '*school hearing score*' ($F_{1,37} = 14.210$, $p < .001$, Adjusted R square .448) where objective noise measures (L_{A90} and L_{A99}) accounted for 45% of the variance in the children's responses. Moreover, a stepwise regression indicated that both measurements contributed unique variance. Children who were in classes in schools with higher underlying external noise levels were reporting higher over all noise awareness.

F. The relationship between teachers' and children's reports of sound source.

Figure 4 shows the ~~percentage-percentages of ratings of noise sources by~~ both children and teachers ~~reporting hearing various sound sources~~.

INSERT FIGURE 4 HERE

To control for artificially inflating the variance accounted for by only using significantly associated measures a second ~~analyses-analysis~~ was computed for '*school hearing score*'

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using all noise levels. These results were similar ($F < 7.38 = 4.7$, $p < .001$, adjusted R square .405).

As shown in Figure 4, teachers reported similar levels of hearing environmental noise sources as the pupils, but teachers reported sirens more often than the children. The correlation between children's and teachers' rankings of sound sources was very high ($r = .945$, $p < .001$). Since the questionnaire was completed by only one teacher in 20 schools, by two teachers in 11 schools and by three teachers in the remaining three schools, it is not possible to calculate correlations with any of the objective noise measures and because of high selection in the teacher sample generalisations cannot be drawn.

V. DISCUSSION AND CONCLUSION

The current study aimed to ascertain children's perceptions of their noise environment and how the children's perceptions related to objective measures of noise. Precision, specificity and consistency of responding were established through the use of convergent measures. The results have confirmed earlier work indicating that children in primary schools are exposed to high levels of environmental noise. In addition the data demonstrate that external school levels influenced the children's reported relative ease of hearing their teacher when other confounding noise sources or classroom teaching contexts were not present. Children and teachers reported hearing similar noise sources in classrooms and children were annoyed by similar sources of noise both at home and school.

Age differences in reported audibility were ~~also~~-noted. Older children reported greater ease of hearing in all conditions where the teacher's face was visible but for this age group hearing was reduced relative to younger children when there was background babble from other children outside in the playground. It appears that the older children may

be making greater use of the information from the teacher's face and are more distracted by speech-like interference (Shield & Dockrell, 2003). However, younger children were often placed in seating arrangements that would detract from hearing well, for example, small groups facing each other around a table. Younger children may also have greater difficulties processing language and maintaining attention (Dockrell & Messer, 1999). These results indicate that primary school children are able to judge situations where they have difficulty hearing the teacher, and that younger children report relatively greater difficulty than older children, although the exact reasons for these developmental differences are not clear from these data.

Children reported hearing a wide range of different sound sources in their classrooms and while there were some age differences in reporting sound sources this variable accounted for little of the variance. In contrast a significant proportion of the variance in children's recorded sound sources was accounted for by school/classroom location. These data are likely to reflect both the school's location and the structure of the building. Moreover children in classrooms where schools had higher objective measures of external background noise levels reported hearing, on average, higher percentages of external sound sources. This rating was related to the background noise levels measured both outside the school and in the classroom.

In contrast to the ratings for hearing the sounds the children's reported levels of annoyance were related to the maximum noise levels recorded outside the schools. There was a clear hierarchy of sounds that were found to be annoying, whether they were heard at home or at school. Trains, motorbikes, lorries and sirens were rated as the most annoying while trees were rated as the least annoying. Correlations between annoyance levels and recorded sound levels were similar to those reported in studies with adults.

The present data indicate that young children are sensitive to noises in their environment and can discriminate noise sources that annoy them. External L_{Amax} levels are a significant factor in reported annoyance whereas external L_{A90} and L_{A99} levels are a significant factor in determining whether or not children hear sound sources. Moreover, the higher the objective [external](#) noise levels recorded for a school, the less likely the children were to report being able to hear the teacher.

Thus, the data from the current study suggest that the impact of different aspects of noise on children's perceptions and behaviours needs to be addressed. The maximum noise levels reflect sporadic episodes that the children find annoying. There is also evidence that unexpected irrelevant sounds influence the performance of adults on specific cognitive tasks (Jones, Alford, Bridges, Trembley & Macken, 1999). Background noise at the levels reported outside these schools are not associated with the children's reported level of annoyance, although it is related to their awareness of noise. Nonetheless high levels of background noise have been found to influence academic attainments.

The data from the current study supports the view that children can be sensitive judges of their noise environments. Future work will need to specify the bases for developmental changes and physical and locational factors that determine the school effects.

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TABLE I

Means and standard deviations of external levels in survey area

$L_{Aeq,5min}$		$L_{A10,5min}$		$L_{A90,5min}$		$L_{Amax,5min}$	
Mean	sd	Mean	sd	Mean	sd	Mean	sd
57.4	8.8	59.4	9.0	49.2	7.7	70.1	10.5

TABLE II

Reported hearing acuity by Year 2 and Year 6 children in different school contexts

Rank	p	Year 2		Year 6	
		Mean	Std Deviation	Mean	Std Deviation
1 - very well					
5 - not at all					
Cannot see teacher's		1.93	0.84	2.34	1.02
Teacher talking	<.001	2.29	0.83	1.96	0.95
and moving					
Working in groups		2.44	0.93	2.39	1.11
No noise outside	<.001	1.90	0.93	1.68	1.10
Children making noise					
outside		2.70	1.08	3.01	1.06
Doing a test	<.001	1.87	0.89	1.53	1.04
PE in playground	<.001	2.79	1.05	2.62	1.09
No noise at all	<.001	1.46	0.83	1.24	0.79
Speaking classmate	<.05	2.47	1.00	2.15	1.00

TABLE III

Percentages of children hearing a particular sound in their classroom and having heard it being annoyed by it

Noise target	Heard			Annoyed		
	Year 2	Year 6	Significance	Year 2	Year 6	Significance
Animal	32.4	25.1	$X^2 = 13.217$ *** ²	44.9	38.4	$X^2 = 2.534$
Phone	36.4	40.9	$X^2 = 4.331$ *	41.0	41.4	$X^2 = .013$
Music	57.0	53.0	$X^2 = 3.919$ *	40.4	34.8	$X^2 = 3.638$
Bus	35.1	37.9	$X^2 = 1.616$	55.9	47.5	$X^2 = 5.213$ *
TV	32.3	22.2	$X^2 = 26.479$ ***	30.1	20.0	$X^2 = 7.229$ **
Motorbike	52.1	58.8	$X^2 = 9.187$ **	58.8	61.1	$X^2 = 0.610$
Car	67.6	73.9	$X^2 = 9.879$ **	53.3	45.0	$X^2 = 9.778$ **
Train	19.1	24.5	$X^2 = 8.474$ **	58.2	66.1	$X^2 = 4.388$ *
Trees	42.4	44.9	$X^2 = 1.316$	22.9	19.7	$X^2 = 1.376$
Helicopter	43.0	53.7	$X^2 = .098$	56.9	46.4	$X^2 = 11.564$ **
Sirens	49.8	69.0	$X^2 = 76.908$ ***	67.6	52.0	$X^2 = 28.097$ ***
Stereo	27.9	34.2	$X^2 = 9.268$ **	47.0	24.7	$X^2 = 33.812$ ***
Planes	55.5	53.5	$X^2 = .776$	47.3	34.6	$X^2 = 18.253$ ***
Lorries	53.4	61.9	$X^2 = 14.556$ ***	58.2	59.1	$X^2 = .90$

Figures in bold are cases where higher reports are made by older children.

² Reported significance levels *** .001, **.01, *.05

TABLE IV

School variation in hear and annoy data with variation accounted for (DF 42)

Noise target	Hear		Annoy	
	Significance	Variation accounted for	Significance	Variation accounted for
Animal	$X^2 = 153.025$ ***	8%	a)	
Phone	$X^2 = 531.147$ ***	26%		
Music	$X^2 = 196.498$ ***	12%		
Bus	$X^2 = 451.864$ ***	22%		
TV	$X^2 = 236.398$ ***	12%		
Motorbike	$X^2 = 390.941$ ***	19%		
Car	$X^2 = 478.470$ ***	24%	$X^2 = 91.822$ ***	6%
Train	$X^2 = 534.662$ ***	26%		
Trees	$X^2 = 158.456$ ***	8%		
Helicopter	$X^2 = 113.344$ ***	6%	$X^2 = 80.744$ ***	7%
Sirens	$X^2 = 186.951$ ***	9%	$X^2 = 80.569$ ***	7%
Stereo	$X^2 = 86.880$ ***	4%		
Planes	$X^2 = 72.309$ **	4%	$X^2 = 86.294$ ***	8%
Lorries	$X^2 = 233.565$ ***	12%	$X^2 = 59.271$ *	5%

a) a blank cell indicates that sig cannot be compute because greater that 5% of cells have expected frequencies less than 5

TABLE V

Children's ranking of hearing in school by sound source and the rank of externally observed sources

Sound source	Rank of child scores	Rank of external observations
Cars	1	1
Sirens	2	11
Lorry	3	3
Motorbike	4	9
Aircraft	5	2
Music	6	8
Helicopter	7	10
Trees	8	6
Bus	9	3
Birds/animals	10	5
Train	11	7

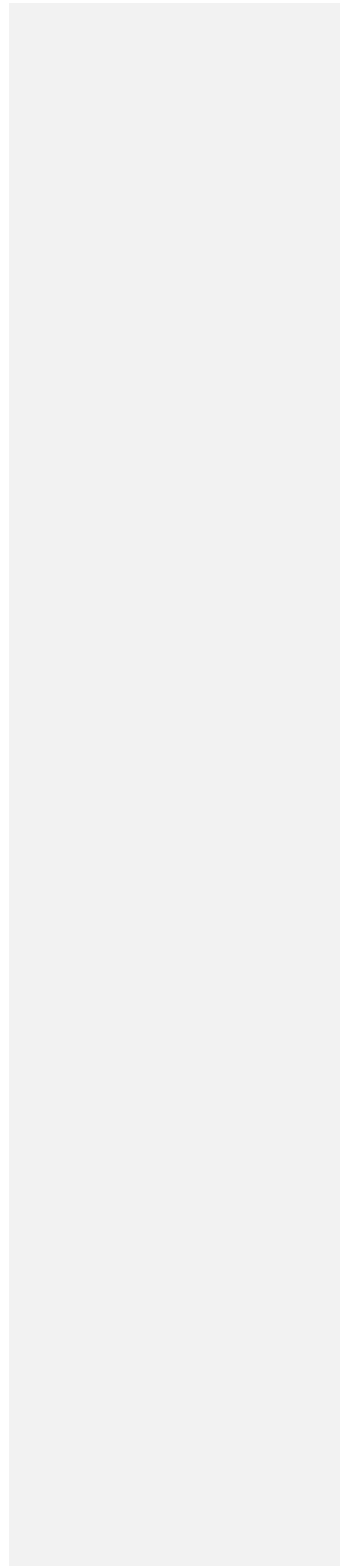
FIGURES

Figure 1. Percentages of occurrences of external noise sources

Figure 2. Mean rank of ability to hear in the nine listening conditions

Figure 3. Percentages of children hearing sound sources at home and at school

Figure 4. Comparison of teachers and children's reporting hearing sound sources at school



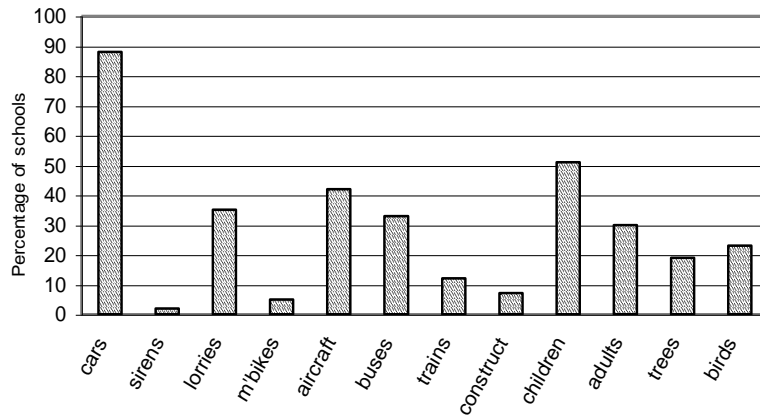


Figure 1. Percentages of occurrences of external noise sources outside school

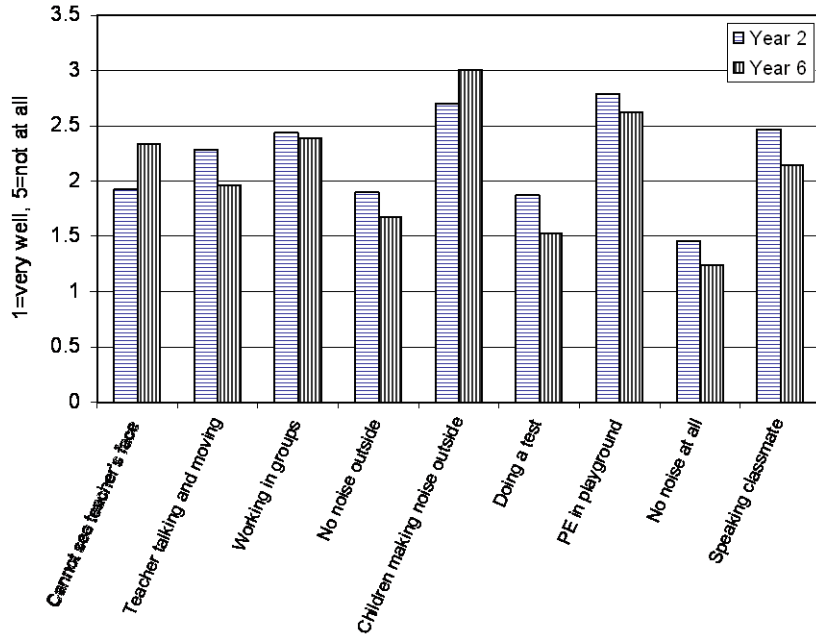


Figure 2. Mean rank of ability to hear in the nine listening conditions

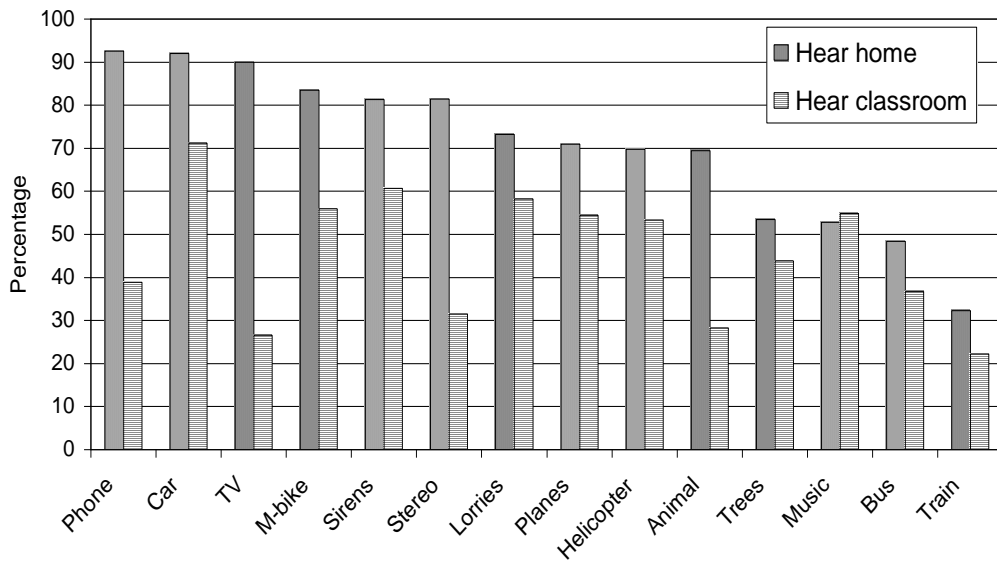


Figure 3. Percentages of children reporting hearing the sound source at home and at school

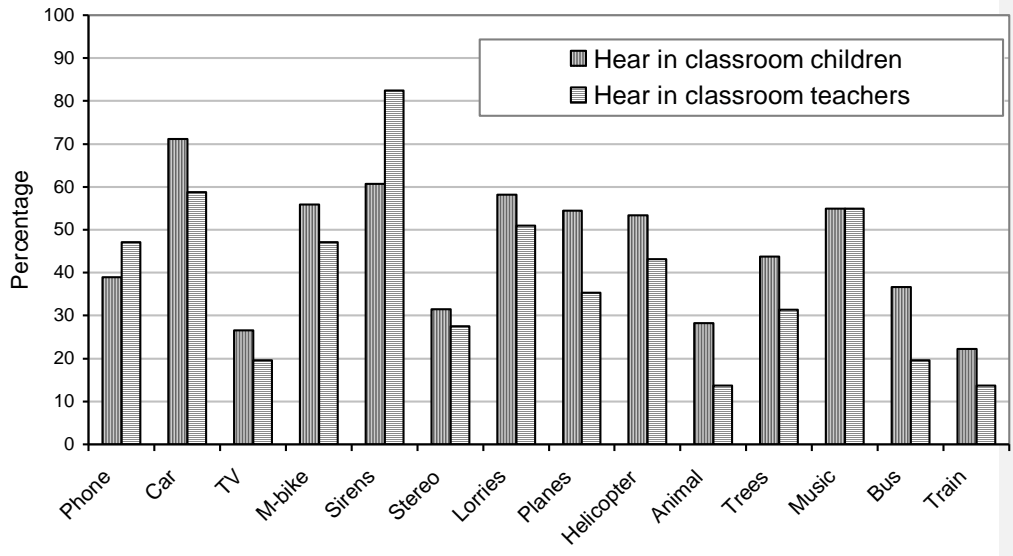


Figure 4. Comparison of teachers and children's reporting hearing sound sources at school

BOX 1

The 'school hearing score', 'school annoy score' and 'child annoy score' are defined as follows:

Let h_s = number of children in a school reporting hearing noise source s

a_s = number of children in a school reporting being annoyed by noise source s

n = number of children in a school who completed questionnaire

Let $H = h_1 + h_2 + \dots + h_{14}$

$A = a_1 + a_2 + \dots + a_{14}$

Then School hHearing sScore = $H/14n$

School aAnnoyance Score = $A/14n$

Child aAnnoyance sScore = A/H

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