The effects of classroom and environmental noise on children's academic performance

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INTRODUCTION

There has been a considerable amount of research in the past 40 years into the effects of noise on the performance of school children (Hetu et al. 1990; Evans & Lepore 1993; Shield & Dockrell 2003). It is generally accepted that noise has a detrimental effect upon the learning and performance of primary school children, and that the older children in this age group are more affected than the younger children (Berglund & Lindvall 1995; Institute for Environment and Health 1997). Activities affected by noise include memory, reading, motivation, and attention (Bronzaft 1981; Cohen et al. 1981; Hygge et al. 1996; Berg et al. 1996; Maxwell & Evans 2000; Lundquist et al. 2000; Haines et al. 2002; Clark et al. 2006). There is increasing evidence that poor classroom acoustics can have a particularly negative effect upon children with special needs such as hearing impairment (Nelson & Soli 2000) or learning difficulties (Bradlow et al. 2003)

This paper presents the results of a project carried out to assess the noise exposure of children at primary schools in London (UK) and to examine the impact of both environmental and classroom noise upon their academic performance. The impact of noise upon performance was examined in two ways: by investigating relationships between internal and external noise levels and children's performance in nationally standardized tests of numeracy, literacy and science; and by experimental testing of children in different classroom noise conditions. It will be shown that the results of the two investigations of the impact of noise were consistent, showing that both environmental and classroom noise have detrimental effects upon children's academic performance; and also that noise has more of an impact upon children with special educational needs than upon other children.

METHOD – COMPARISON OF NOISE AND TEST RESULTS

The initial part of the study consisted in carrying out internal and external noise surveys of London schools (Shield & Dockrell 2004). A questionnaire survey of over 2,000 primary school children was also undertaken, in which children's perceptions of noise sources heard and annoyance from noise were assessed (Dockrell & Shield 2004). Noise levels were correlated with school results in nationally standardized tests (Shield & Dockrell 2008).

Demographic data on each of the surveyed schools were obtained from the government Department of Children, Schools and Families (DCSF), in order to control for socio-economic factors in the analysis. This data consisted of the percentage of children receiving free school meals (FSM); the percentage of children for whom English was an additional language (EAL); and the percentage of children with special educational needs (SEN). The FSM score has been shown to be a reliable indicator of social disadvantage in an area (Williamson & Byrne 1977).

Noise surveys

Noise levels were measured outside 142 schools within eight miles of central London (Shield & Dockrell 2004). Areas of London where aircraft are the predominant noise source were avoided as there was already a considerable body of research into the effects of aircraft noise (Evans & Lepore 1993; Cohen et al. 1981; Hygge et al. 1996; Haines et al. 2002). The main noise source to which the surveyed schools were exposed was therefore road traffic.

The schools surveyed were all state primary schools in three London boroughs: borough A was an ‘outer’ borough situated around six to eight miles of central London; the other two boroughs, B and C, were close to central London. Different characteristics of the boroughs can be illustrated by their respective population densities. The average noise levels measured in each borough are shown in Table 1, together with population densities and average school socio-economic factors.

Table 1: External noise levels and demographic data for primary schools in three London boroughs

Borough	Noise levels			Socio economic factors			Population/km^2
	L_{Aeq}	L_{A90}	L_{Amax}	%FSM	%EAL	%SEN	
A	57.4	49.2	70.5	38.8	43.9	10.3	7,600
B	56.2	46.5	68.3	41.5	35.3	28.3	12,200
C	58.9	50.2	72.0	33.6	39.6	26.2	10,100

Internal noise surveys were carried out in occupied and unoccupied spaces in 16 schools in boroughs A and B, chosen to reflect the full range of external noise levels. Spaces measured included 110 occupied classrooms and 30 empty classrooms. Internal levels measured are summarized in Table 2.

Table 2: Noise levels inside London schools

Noise level	Occupied classrooms	Empty class-rooms	Corridor/ foyer	Occupied halls	Empty halls
L_{Aeq}	72.1	47.0	58.1	73.4	53.2
L_{A90}	54.1	36.9	44.6	55.1	44.3

Standardized assessment tests (SATs)

Primary school children in England and Wales take standardized tests in English, Mathematics and Science at the ages of seven (‘Key Stage 1’) and eleven (‘Key Stage 2’) years. Average results for each school, consisting of the percentages of children achieving a specified criterion level at each stage, are published by DCSF. At the time of the study the tests taken at each stage were as follows:

Key Stage 1 – Reading, Writing, Spelling, Mathematics
Key Stage 2 – English, Mathematics, Science

METHOD - COGNITIVE TESTING IN NOISE

Children performed a series of cognitive tests in three different noise conditions, which were based upon the results of the classroom noise and questionnaire surveys.

Tests

A battery of verbal and non-verbal tests appropriate for eight year old children was developed (Dockrell & Shield 2006). The verbal tests consisted of two measures of literacy: a reading test and a spelling test. Two non-verbal tests were used: a speed of performance test designed to assess how quickly a child can perform simple mental operations, and a written arithmetic test.

Subjects

The tests were performed by 158 eight year old children from six classes in four schools. The schools were matched for external noise levels, social disadvantage as measured by FSM scores, and SATs results. Of the children 38 (24 %) were identified as having recognized special educational needs.

Noise conditions

The children performed the tests in one of three noise conditions, derived from the results of the internal and external noise surveys of schools and children's questionnaire responses concerning noise sources heard in the classroom (Shield & Dockrell 2004; Dockrell & Shield 2004). The three noise conditions were as follows:

- *base*, that is their normal classroom condition when the children are working quietly with no talking and no additional noise
- *babble*, that is children's babble, played at a steady level of 65 dB(A) L_{Aeq}, this being the average level measured in classrooms when children were working individually (Shield & Dockrell 2004)
- *babble and environmental noise*, that is children's babble as in the '*babble*' condition, with intermittent noise events from various sources (eg sirens, lorries) at random intervals, at a level of 58 dB(A) L_{Amax} (that is the average internal level estimated from the external L_{Amax} levels measured outside schools)

Classes were randomly assigned to one of the three noise conditions. All children carried out all tests in their allocated noise condition.

RESULTS

This section presents the results of the two different investigations of the effects of noise, and also of the effects of noise upon children with SEN.

Effects of noise on standardized test results

All internal and external noise parameters were correlated with Key Stage 1 (KS1) and Key Stage 2 (KS2) SATs scores for each subject, plus school average scores for each stage. The outer and central boroughs were treated separately in the analysis. Results were very similar for all KS1 literacy tests (Reading, Writing, Spelling) as would be expected. Therefore in the following discussion results are presented only for KS1 Reading to illustrate the impact of noise on the younger children's attainments in literacy.

For the outer borough, borough A, significant negative relationships existed between all SATs scores and all external noise parameters, except for KS1 Mathematics and L_{Amax}, as shown in Table 3. However, this pattern was not repeated for central boroughs B and C when all schools were considered. If only those schools in boroughs B and C with external levels greater than 60 dB L_{Aeq} (the level specified as the upper limit at the site boundary in UK guidance on selection of a site for a new school) were considered, then there were significant negative correlations between test and noise parameters as also shown in Table 3.

Obviously many factors apart from noise affect children's academic performance. To control for the schools' socio economic status as represented by FSM, EAL and SEN data, partial correlation was carried out. Many of the negative relationships between noise and tests scores were still significant, as shown in Table 4, which presents the significant correlation coefficients between L_{Aeq} and L_{Amax} and Key Stage 2 test scores when controlling for socio-economic factors.

Table 3: Significant (at 1 % or 5 %) correlation coefficients between external noise and SATs results

Borough	Noise level	Key Stage 1			Key Stage 2			
		Reading	Maths	Average	English	Maths	Science	Average
A	L_{Aeq}	-0.34	-0.31	-0.36	-0.37	-0.40	-0.40	-0.41
	L_{Amax}	-0.31		-0.32	-0.39	-0.46	-0.45	-0.45
	L_{A90}	-0.37	-0.43	-0.40	-0.40	-0.40	-0.42	-0.43
B & C (L_{Aeq}>60)	L_{Aeq}	-0.40			-0.39			
	L_{Amax}	-0.40			-0.43		-0.36	-0.39
	L_{A90}				-0.37			

Table 4: Significant (at 1 % or 5 %) correlation coefficients between external noise and KS2 SATs results when correcting for socio-economic factors

Borough	Factor	L_{Aeq}				L_{Amax}			
		English	Maths	Science	Ave	English	Maths	Science	Ave
A	FSM						-0.36	-0.34	-0.36
	EAL	-0.27	-0.32	-0.32	-0.33	-0.38	-0.44	-0.42	-0.45
	SEN	-0.34	-0.38	-0.39	-0.39	-0.37	-0.44	-0.44	-0.44
B & C (L_{Aeq}>60)	FSM	-0.34				-0.46		-0.35	-0.41
	EAL	-0.37				-0.46	-0.32	-0.37	-0.41
	SEN					-0.48	-0.34	-0.37	-0.43

Tables 3 and 4 show that all test scores were negatively correlated with noise levels. In borough A all except one relationship was significant at the .01 or .05 level, the strongest correlations being for KS2 Maths and Science. In boroughs B and C the subject score most closely associated with noise was KS2 English. In all boroughs the noise parameter most closely associated with noise was L_{Amax}, and KS2 scores were more strongly related to noise than KS1 scores. This pattern is maintained when data are controlled for school socio-economic factors.

A scatter plot illustrating the relationship between external L_{Amax} levels and average KS2 scores in borough A is shown in Figure 1.

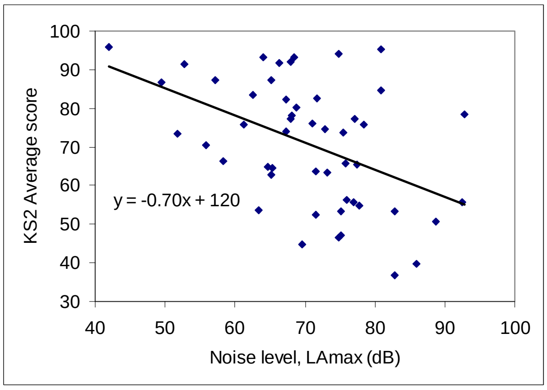

Figure 1: Scatter diagram relating external L_{Amax} levels and average KS2 test scores in borough A

For the analysis of the effects of internal noise on test scores all 16 schools were considered together. Internal noise levels measured in different school locations were compared with test scores. Negative correlation coefficients were found between all subject test scores and noise levels measured in occupied and unoccupied classrooms and in corridors and foyers. The strongest correlations were with noise levels measured in occupied classrooms, particularly L_{A90} levels. Table 5 shows the significant correlation coefficients between test scores and L_{Aeq} and L_{A90} levels in occupied classrooms. When correcting for socio-economic factors there were still significant negative correlations between L_{A90} levels in occupied classrooms and noise; these are also shown in Table 5.

Table 5: Significant (at 1 % or 5 %) correlation coefficients between noise in occupied classrooms and SATs results

SATs stage	Subject	L_{Aeq}	L_{A90}	Correcting for socio economic factors L_{A90}		
				FSM	EAL	SEN
Key Stage 1	Reading		-0.60			-0.60
	Maths		-0.57			-0.60
	Average		-0.58			
Key Stage 2	English	-0.55	-0.77	-0.66	-0.69	-0.76
	Maths					
	Science		-0.50			-0.59
	Average		-0.64	-0.51	-0.54	-0.63

A scatter plot illustrating the relationship between L_{A90} levels in occupied classrooms and average KS2 scores is shown in Figure 2.

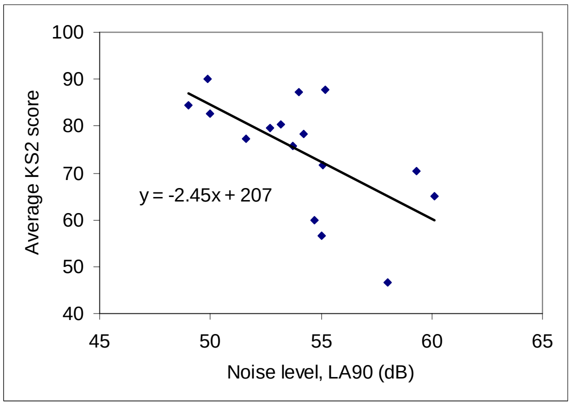

Figure 2: Scatter diagram relating occupied classrooms L_{A90} levels and average KS2 test scores

Effects of noise on verbal and non-verbal reasoning

Table 6 shows the means and standard deviations of the children's performance scores in the cognitive tests in the three different noise conditions.

Table 6: Children's performance scores in three noise conditions

Test	Max poss score	Base		Babble		Babble + env noise	
		Mean	sd	Mean	sd	Mean	sd
Reading	75	33.45	11.62	27.59	12.23	39.48	8.95
Spelling	15	9.55	3.89	7.18	4.59	11.68	2.75
Arithmetic	17	8.00	2.96	6.86	2.74	8.70	2.83
Speed (no correct answers)	75	44.62	21.85	37.35	16.63	30.02	9.14

Statistical analysis showed that there was a significant effect of noise condition for the speed of information processing task (number of correct answers). This relationship held after controlling for gender and overall ability (as indicated by an additional ability test). Children in the *base* condition scored significantly better than children in the *babble* ($p<.05$) and *babble and environmental* noise ($p<.001$) conditions. In the same test children missed significantly more items in the *babble and environmental* noise condition than in the *babble* condition ($p<.01$), and significantly more in the *babble* condition than in the *base* condition ($p=.05$).

There was also a significant effect (after controlling for gender and ability) of noise condition on the verbal tasks, both reading and spelling. For both tests children in the *babble* condition performed worse than children in the *base* condition; however, unexpectedly, children in the *babble and environmental* noise condition performed significantly better than children in the *base* ($p<.05$) and *babble* ($p<.001$) conditions. The better performance in *babble and environmental* noise may be because this condition encouraged children to actively focus on the task, possibly by redirecting attention. It is unlikely, however, that this effect would be observed over a long period of exposure; further research is necessary to examine this in more detail.

There was a similar pattern for the arithmetic test: children performed significantly better in the *base* condition than in *babble* ($p<.01$); however performance in the *babble and environmental* noise condition was not statistically significantly different to that in the other two conditions.

Effects of noise on children with special needs

When considering overall scores for the experimental tests, children with special educational needs performed significantly worse in all tests, except the non-verbal speed of processing test, than the other children.

However, these children were affected differentially to the typically developing children by the noise conditions in the reading, spelling and speed of processing (number of correct items) tests. Table 7 shows the mean scores for the two groups of children in the three noise conditions for these tests. It can be seen that, while the *babble* condition results in reduced scores overall for reading and spelling, children with SEN are more severely affected than the other children. However, unlike the typical children those with SEN were not affected by *babble* in the speed of performance test. It can also again be seen that, surprisingly, the introduction of environmental noise to the classroom babble improved performance for both groups in the reading and spelling tests.

Table 7: Mean performance scores of typical children and children with SEN in three noise conditions

Test	Max poss score	Base		Babble		Babble + env noise	
		Typical	SEN	Typical	SEN	Typical	SEN
Reading	75	35.50	28.00	30.76	13.44	40.36	36.93
Spelling	15	10.20	7.80	8.28	2.33	11.78	11.43
Speed (no correct answers)	75	49.20	32.40	36.96	39.00	20.90	30.36

DISCUSSION

The comparison of noise levels and SATs results showed that both external and internal classroom noise have a detrimental impact upon children's academic performance, with older children in the primary school age range being more affected than the younger children. The younger children were more affected by ambient and background levels of external noise, while the test scores of the older children were more closely related to maximum noise levels. This suggests that the performance of the older children is affected by the noise of individual events such as sirens, lorries or motorbikes passing the schools. This is consistent with the results of a questionnaire survey into children's perceptions of noise and its effects (Dockrell & Shield 2004) carried out during the same period, which showed that older children were more aware of external noise and that annoyance was related to external L_{Amax} levels. The impact of noise of indivdual events is also consistent with the findings of research into the effects of aircraft and railway noise on children's performance (Cohen et al. 1981; Bronzaft 1981; Hygge et al. 1996; Haines et al. 2002; Clark et al. 2006).

Differences were found in the relationships between noise and test scores in the three areas of London which participated in the survey. In the central boroughs effects of noise on test scores were only found for those schools where the external noise levels exceeded 60 dB(A) L_{Aeq}. A possible explanation is that schools in these two areas have a considerably higher percentage of children with special needs than in the other borough, which may result in 'floor' effects in these areas; that is, no matter how quiet the area around the school test results would not improve above a certain level. However, for the 'noisier' schools the general pattern of noise effects was similar to that in the outer borough.

It was found that internal noise levels were more closely related to test results than external levels, again particularly for the older children. Background (L_{A90}) levels in occupied classrooms were found to be the most closely associated with test scores; this is likely to be the level of general background classroom noise, such as background 'chatter'.

This finding was consistent with the results of the controlled experimental testing which found that classroom *babble* had a detrimental effect upon children's performance in verbal and non-verbal tasks. Surprisingly performance in some tasks improved in *babble and environmental* noise. However, the age of the children in these tests was close to that of the younger children in the SATs/noise study which found that environmental noise had more of an impact upon the older children than the younger ones, and in particular that the younger children were more affected by ambient and background noise and the older children by maximum noise levels, that is the noise of individual events. The only experimental task in which the children performed worst in *babble and environmental* noise was the speed of information processing task. These results may explain why test scores for KS2 English were particularly strongly related to internal classroom background noise levels, while (in Borough A) KS2 Mathematics scores were the ones most strongly related to external L_{Amax} levels.

The experimental testing also found that children with special educational needs are particularly susceptible to detrimental effects of classroom babble upon their performance in verbal tasks (reading and spelling). However, interestingly the children with SEN did not appear to experience the same detrimental effect of *babble* as the other children in the speed of information processing task. It thus appears that children with SEN are less able to process language in classroom babble, but are less distracted by babble than other children when performing non-verbal tasks.

CONCLUSIONS

The results show that both chronic and acute exposure to environmental and classroom noise have a detrimental effect upon children's learning and performance. For external noise it appears to be the noise of individual events which have the most impact, while background noise in the classroom also has a significant negative effect. Children with special educational needs were found to be more susceptible to the effects of classroom babble upon verbal tasks than other children. These results raise specific challenges for national and international policies which aim to educate all children in 'inclusive' environments.

These studies have shown that it is essential to give careful consideration to the acoustic design of a school in order to optimize conditions for teaching and learning. The siting and internal layput of a school should be such that classrooms are not exposed to high levels of external noise. Also individual classrooms should be sited and designed so that background noise levels are miminised.

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