# Acoustical barriers in classrooms: the impact of noise on performance in the classroom[1]

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**Abstract**

There is general concern about the levels of noise that children are exposed to in classroom situations. We report the results of a study that explores the effects of typical classroom noise on the performance of primary school children on a series of literacy and speed tasks. One hundred and fifty eight children in six Year 3 classes participated in the study. Classes were randomly assigned to one of three noise conditions. Two noise conditions were chosen to reflect levels of exposure experienced in urban classrooms (Shield & Dockrell, 2004): noise by children alone, that is classroom–*babble*, and *babble* plus environmental noise, *babble and environmental*. Performance in these conditions was compared with performance under typical quiet classroom conditions or *base*. All analyses controlled for ability. A differential negative effect of noise source on type of task was observed. Children in the *babble and environmental* noise performed significantly worse than those in the *base* and *babble* conditions on speed of processing tasks. In contrast, performance on the verbal tasks was significantly worse only in the *babble* condition. Children with special educational needs were differentially negatively affected in the *babble* condition. The processes underlying these effects are considered and the implications of the results for children's attainments and classroom noise levels are explored.

## Introduction

The ways in which classroom acoustics can impact on children's learning and attainments has been relatively neglected in educational circles. Yet there is increasing evidence that poor classroom acoustics can create a negative learning environment for many students (Shield & Dockrell, 2003), especially those with hearing impairments (Nelson & Soli, 2000), learning difficulties (Bradlow *et al.*, 2003) or where English is an additional language (Mayo *et al.*, 1997). Moreover, excessive noise in the classroom can serve as a distraction and annoyance for teachers and pupils alike (Dockrell & Shield, 2004). To address these concerns many countries have recently introduced or revised legislation and guidelines relating to the acoustics of schools, for example 'Building Bulletin 93: Acoustic Design of Schools' in the UK (DfES, 2003) and ANSI standard S12.60 'Acoustical Performance Criteria, Design Requirements and Guidelines for Schools' (ANSI, 2002) in the USA. The purpose of such guidelines is to improve the teaching and learning conditions for pupils and teachers in schools. In this paper we explore the effects of typical classroom noise on the performance of primary school children on a series of literacy and speed of processing tasks. Noise conditions were chosen to reflect levels and sources of exposure experienced in urban classrooms (Shield & Dockrell, 2004). Performance under the different conditions is analysed and separate analyses consider the differential effect, if any, for children with English as an additional language and for children with Special Educational Needs.

### *Acoustic design of classrooms*

There are two main aspects to the acoustical environment of classrooms: noise and reverberation. Noise inside a classroom may be due to a number of factors, for example noise from outside, noise from building services (heating, lighting, ventilation systems), noise of teaching aids (overhead projector, computers) and noise from the children themselves. The quality and intelligibility of speech in a classroom depends both on the level of noise and on the amount of reflected sound. Sound is reflected off all surfaces in the room including walls, ceiling, floor, tables and whiteboards. The harder or more reflective the surface, the greater the amount of sound that is reflected back into the room. The reflections ‘bounce’ around the room being repeatedly reflected until all the sound energy is dissipated. Too much reflected sound degrades the quality of speech by increasing the noise level and masking speech. The amount of reflection is quantified by the ‘reverberation time’ of the room, which is the time in seconds that it takes for a sound to decay by 60 dB, in effect the time it takes for a sound to become inaudible. For speech the reverberation time should be short, of the order of 0.4 to 0.8 seconds for classrooms, whereas for music longer times of around 2 seconds are desirable. The reverberation time can be reduced by increasing the amount of acoustic absorption in the room, for example by installing acoustic ceiling tiles, carpet or curtains. Speech intelligibility is also related to the signal to noise (S/N) ratio, which is the difference between the signal (in this case, speech) and background noise in a room.

### *Noise in schools*

Two different sources of noise can influence the acoustic environment of the classroom: environmental noise and noise generated by the children themselves. The predominant external noise source, particularly in urban areas, is likely to be road traffic (BRE, 2002; Shield & Dockrell, 2002) although both aircraft noise and railway noise can affect schools in specific locations.

Noise is measured in decibels (dB). The decibel is a logarithmic unit which means that a doubling of sound energy, caused for example by doubling the number of speakers in a room, results in an increase in noise level of 3 dB. Environmental noise is usually measured using the A weighted decibel, dB (A), which approximates to the response of the human ear to sound. Some examples of typical noise levels are: leaves rustling 10 dB (A); refrigerator humming 40 dB (A); washing machine 70 dB (A); football crowd 110 dB (A). Subjectively, an increase in noise level of 10 dB (A) corresponds roughly to a doubling of loudness.

Many guidelines for environmental and building acoustics, such as the recently published DfES guidelines on school acoustics Building Bulletin 93: Acoustic Design of Schools (DfES, 2003), express noise levels in terms of the 'equivalent continuous sound level', $L_{Aeq}$. The $L_{Aeq,T}$ is the level in dB (A) averaged over a time period T. The maximum level in dB (A), which occurs during a time period T, is denoted by $L_{Amax,T}$. In a noise survey of schools carried out by the authors (Shield & Dockrell, 2004), external levels were measured over 5 minute periods outside 142 schools to give $L_{Aeq,5min}$ and $L_{Amax,5min}$. Internal $L_{Aeq}$ levels were measured in 140 classrooms.

Studies have shown a wide range of noise levels in classrooms (Airey, 1998; Celik & Karabiber, 2000; Hay, 1995; Hodgson, 1994; Mackenzie, 2000, Moodley, 1989, Shield & Dockrell, 2004). In a survey of seven primary school classrooms background noise levels in empty classrooms ranged from 35 to 45 dB (A) $L_{Aeq}$ and in occupied classrooms, with the children talking and working, from 58 to 72 dB (A) $L_{Aeq}$ (the lower levels being measured in those classes with an experienced teacher and the higher levels when a trainee teacher was taking the class) (Hay, 1995). The average noise level measured by Shield and Dockrell (2004) in empty primary school classrooms in central London was 47 dB (A) $L_{Aeq}$, which was similar to average levels found in previous surveys of UK classrooms, for example 45 dB (A) in studies by Airey and Mackenzie (1999), and Moodley (1989). Building Bulleting 93 (DfES, 2003) recommends an upper noise limit of 35 dB (A) $L_{Aeq\ 30\ min}$ for unoccupied primary and secondary school classrooms.. The overarching conclusion is that in many classrooms average noise levels exceed current guidelines and are likely to compromise children's ability to hear the teacher and their peers.

Recently Shield and Dockrell (2004) have attempted to characterise the typical exposures received by children in urban schools. They found that the average $L_{Aeq}$ of occupied teaching spaces, which can be assumed to represent a typical daily noise exposure for a child at school, was 72 dB (A). However, within a school the internal noise levels in a classroom fluctuate widely depending upon the activity in which the children are engaged. The most important factor in determining classroom noise level was found to be the classroom activity, with a difference of approximately 20 dB (A) between the quietest and noisiest activities. Of particular importance was the finding that external noise appeared to have little effect on internal noise levels except when children were engaged in the quietest activity in the classroom. These results suggest that classroom management and organisation can have a significant impact on the acoustic environment of a classroom. Nonetheless, despite their best efforts to listen, students can be distracted by noises from both inside and outside the classroom, and teachers are not necessarily equipped with the skills to moderate the effects of noise (Dockrell, Shield & Rigby, 2004).

### *The impact of noise on children's learning and attainments*

Investigations over the last 30 years have documented the detrimental effects of excessive noise levels on children's cognitive processing and academic performance. Much of the published work on the effects of noise has focussed on the impact of external noise, in particular on pupils in schools exposed to aircraft noise. Research in the early 1970s found that in schools around Heathrow Airport aircraft noise had a significant impact on teaching by interfering with speech and causing changes in teachers' behaviour in the classroom (Crook & Langdon, 1974). These initial results have been confirmed and extended by subsequent research which has indicated that high noise exposure is associated with poor long term memory and reading comprehension, and decreased motivation in school children (Cohen *et al.*, 1980; Evans & Lepore, 1993; Haines *et al.*, 2001a; Haines *et al.*, 2001b). The negative impact of external noise is not restricted to aircraft noise. Other studies have examined the effects of school exposure to train and road traffic noise (Bronzaft, 1981; Bronzaft & McCarthy, 1975; Lukas *et al.*, 1981; Sanz *et al.*, 1993). These studies have demonstrated effects on both reading (Bronzaft & McCarthy, 1975; Lukas *et al.*, 1981) and attention (Sanz *et al.*, 1993).

While it appears from all these studies that chronic exposure to particular sources of environmental noise may adversely affect children's academic performance, there are many other factors, often unreported, that may influence performance and interact with the effects of noise. These include school, teacher and child-based factors. For example a high correlation between a school's external noise level and the percentage of children having free school meals at the school has been identified for inner city schools (Shield *et al.*, 2002). Since the number of children eligible for free school meals has been recognised as an indicator of social deprivation in an area (Higgs *et al.*, 1997; Williamson & Byrne, 1977) this suggests that deprived children already living in noisy areas attend schools where their exposure to environmental noise may additionally negatively affect their academic performance.

There has been less research directed at the effects of noise occurring in the classroom. However, research in this area is increasing. The general consensus of these studies is that there are indeed detrimental effects on children's reading, numeracy and overall academic performance (Airey & MacKenzie, 1999; Lundquist *et al.*, 2000; Maxwell & Evans, 2000). Moreover when classrooms are acoustically treated, thereby reducing background noise levels and reverberation times, children’s performance on word intelligibility tests improves; this improvement is particularly marked when other pupils are talking in classrooms (Airey & MacKenzie, 1999).

### *The nature of the noise source*

As we have seen children in classrooms are exposed to a range of different noise sources. To implement appropriate noise reduction strategies it is important to identify the effect of specific noise sources on specific performance and behavioural variables. Currently children in junior school classrooms in the UK spend most of the time in whole class or group situations in the presence of their peers (Galton *et al.*, 1999)

There are empirical reasons to predict that classroom noise from children and noise from the environment will influence learning and performance in different ways.

Studies with adults of the effects of irrelevant noise have highlighted the importance of the variation in the sound sources heard in the disruption of tasks (Hughes & Jones, 2001; Jones *et al.,* 1992). In contrast background speech is seen to have its most profound effect on performance on verbal tasks (Banbury & Berry, 1995, 1997, 1998; Tremblay *et al.*, 2000). This would suggest that intermittent sources of sound, such as traffic, might be more disrupting to tasks requiring attention, while the noise from other children in the classroom may interfere, predominantly, with language based tasks. Results obtained with adults cannot, necessarily, be generalised to children. However, if similar patterns of performance were evident in children such data would provide teachers with important information relevant to classroom organisation and teaching strategies. Guidance would also be available to budget holders for the use of funding for classroom modifications.

Children are not equally at risk from noise interference. Children without additional learning needs may function adequately in an acoustically marginal classroom whereas those with learning or language-based problems may be differentially disadvantaged. There is limited (Johansson, 1983; Larway, 1985; Maser *et al.,* 1978), and equivocal evidence (Fenton *et al.,* 1974; Nober & Nober, 1975; Steinkamp, 1980) to support this view. In support of this contention Cohen *et al.* (1986) found that children who have lower aptitude or other difficulties were more vulnerable to the harmful effects of noise on cognitive performance. More specifically, early laboratory research indicated that only children with suspected learning disabilities had difficulties in tracking an auditory signal against a background of competing, irrelevant speech (Lasky & Tobin, 1973). By corollary, sentence processing in white noise is more adversely affected for children with learning disabilities than children without such problems (Bradlow *et al.,* 2003). There is a gradual indication that children who already have difficulties in learning may be subjected to a secondary impediment resulting from the environment in which they learn. Such studies, typically, do not involve assessment of classroom-based performance. If substantiated in classrooms these results raise important issues in relation to current legislation that emphasise equal access to educational opportunities (SENDA act) and raising achievement for all (DfES, 2004). It is therefore important to establish to what extent, if any, noise impacts on classroom performance, and whether certain cohorts of children are differentially negatively affected.

**Purpose**

Experimental investigations of the effects of noise on children's performance in school contexts must consider a number of factors. There should be a clear specification of the noise level, which should be based on the levels expected in classroom conditions; that is, the experimental noise exposure should reflect valid classroom exposures. Specific consideration needs to be given to the type of sound source, whether speech is included and whether or not other unpredictable sound sources are involved. The children's performance that is assessed should include both verbal and non-verbal measures, as well as tasks involving high attention demands. Finally, consideration should be given to the child's general level of ability and how this interacts with performance under noise conditions. The current study addresses these issues by examining the impact of different types of classroom noise on the performance of Year 3 children on a range of literacy and speed tasks.

## Methods

### *Participants*

Six Year 3 classes in four primary schools in north London were selected to take part in the study.  The schools were matched for external noise levels, for percentages of children receiving free school meals (a reliable indicator of social disadvantage) and for Standard Assessment Test results. A total of 158 children (67 boys and 91 girls) in Year 3 took part in the study. The children had a mean age of 8 years 6 months. Sixty-five per cent (*N* = 102) reported that their home language was English, although a minority spoke other languages in addition, while 35% (*N* = 56) reported that their home language was not English. The children spoke a variety of other languages at home including Turkish, Portuguese, French, Chinese and Yoruba.

As a group the children reflected a normal distribution of ability and reading levels. Forty-one percent of the sample scored within the middle range for the group intelligence test AH4 (see below) with a further 45.6 per cent in the top 30%. Twelve per cent fell in the lowest 30%. The mean standard score on the Suffolk Reading Scale was 96 (*SD* = 12.1).

Fifty-six children (35%) had experienced an ear infection in the previous 12 months and 38 children (24%) had a recognized special educational need. Children with special educational needs were identified by their schools and were at Stage 3 or above on the Code of Practice (Department for Education and Science, 1994). Due to confidentiality it was not possible to examine Individual Educational plans or Statements of Special Educational Needs or testing profiles. However, teachers described the children as predominantly having difficulties with literacy and this is substantiated by their mean standard score on the Suffolk Reading Scale ($M$ = 89.8, $SD$ = 13.9).

The children reported a range of noise levels in their classrooms with 11% stating that their classrooms were very noisy and 23% that their classrooms were very quiet, with the majority 39% stating that the noise levels were ‘ok’. These match data reported for similar school settings in London (Dockrell & Shield, 2004). Thus as a group the participants reflect a typical Year 3 urban population.

***Design***

A mixed experimental design was used, with three between- group variables (noise conditions – *base*, *babble* and *babble and environmental* noise) and five within-group measures (assessments). All children completed an ability test and four assessments in a preset order: two verbal, one non-verbal with two outcome measures, and an arithmetic test. Classes were randomly assigned to one of the three noise conditions.

***Materials***

*Aptitude*

The AH4 ability test was used to control for ability in test performance.

This is a group test of general intelligence (Heim *et al.*, 1972). The test provides an overall score, providing normative data and subtests on four different dimensions – series, likes, analogies, and differences.

*Verbal tests*

The verbal tests used consisted of two measures of literacy: a reading and a spelling test. These tests differentiated between a measure of auditory processing (spelling) and linguistic processing (reading).

*(a) Reading*

The reading test used the Suffolk Reading Scale, which is a multiple-choice standardised test of reading ability aimed at different age groups. The present study used the Level 1 reading scale, intended for children attending lessons in school Years 2 and 3. The total testing time is 40 minutes although the children's actual working time is 20 minutes. The score for each child was based on the number of correct answers to the questions asked, out of a possible 75 items.

*(b) Spelling*

A 15 item spelling test was created from age appropriate items on the British Abilities Scale (Elliot *et al.,* 1997). Items were chosen to reduce floor and ceiling effects. An error analysis was designed to examine phonologically similar items, phonologically distant items and items missed.

*Non-verbal tests – speed of information*

The speed of information processing test was developed from the British Abilities Scales (BAS) II (Elliott *et al.,* 1996). The scale assesses how quickly a pupil can perform simple mental operations. Children needed to process a sequence of circular stimuli with small squares inside and decide which circle had the most squares. Each item of the scale consisted of a row of circles (3, 4 or 5) each of which contained a number (1 to 4) of small squares. There were two versions, each one with 15 pages, and five items in each page; a total of 75 items. The test was time limited to two minutes. Children recorded their responses by ticking the circle with the most squares in it. Scores were computed for both the number of correct responses and the number of pages completed. An error analysis was derived to examine missed items and incorrect items. Thus, the speed task provided three outcome measures: items, pages, and error analyses.

*Arithmetic*

Children also completed an paper and pencil arithmetic test. This test involved basic computations but no verbal component. Children worked through the test at their own speed.

***Noise conditions***

Three different classroom noise conditions were used. The three noise conditions were derived from the results of the internal and external noise surveys, and children's questionnaire responses relating to noise sources heard in the classroom (Dockrell & Shield, 2004; Shield & Dockrell, 2004). The three noise conditions chosen were as follows:

*base*, that is the normal classroom condition when the children are working quietly, with no talking and no additional noise

*babble*, that is noise consisting of children's babble

*babble and environmental* noise, that is children's babble as in the second condition plus intermittent environmental noise.

Recorded children's babble was used as the noise for the *babble* condition. During the tests the babble was played at a continuous level of 65 dB (A) $L_{Aeq}$, this being the average level measured in classrooms when children were sitting working individually (Shield & Dockrell, 2004). For the *babble and environmental* noise condition the sounds of various sources were recorded over the babble. The choice of sources was based upon the children's perceptions of noise as reported in the questionnaire survey (Dockrell & Shield, 2004) of children in their classrooms. The noise sources that the children had found most annoying, such as sirens and lorries, were recorded at random intervals over *babble* to provide the *babble and environmental* noise condition. The babble was again played at 65 dB (A), and the level of the external noise events was determined from the maximum levels of individual events recorded during the external noise survey of London primary schools (Shield & Dockrell, 2004). The external levels were assumed to be attenuated by transmission through a classroom façade with closed windows, giving internal levels of 58 dB (A) $L_{Amax}$ for external noise events, which were clearly discernible in the babble.

**Procedure**

Classes were randomly allocated to one of the three noise conditions with the proviso that no two classes in the same school had the same exposures. School and parental approval for the study was obtained following British Psychological Society guidelines. At the beginning of the session, there was a brief introduction about the project, the children being told that the information was for the researchers and not available to the school. They were assured of the anonymity of the school and that no one other than the research team would have access to their individual results. Children were debriefed at the end of the testing sessions.

On the first occasion of testing children filled in a brief questionnaire about their background and their views of the noise in their classroom. The exposure to noise conditions occurred only during the completion of the tests to ensure that the children could hear the test instructions. Before each test the methods of answering were explained and the children were able to work through some practice items. Any problems with the tests were dealt with at the practice stage. The children were told that they had 20 minutes to complete the reading test. For the speed of information processing test children were told that they had 2 minutes to complete the task and that they should therefore do it as fast as possible without making mistakes.

**Results**

The results are presented in three sections. Firstly we consider the overall pattern of performance across the tasks; given the high numbers of participants with English as an additional language their pattern of performance is then described; finally we compare the differential patterns of performance between the children with and without identified special educational needs. The performances of all children on the tests are presented in Table I, which shows the means and standard deviations of the scores for each test in the three different noise conditions.

INSERT TABLE I ABOUT HERE

It can be seen from Table I that in the two verbal tasks (reading and spelling) the performance is worst in the *babble* condition and best in the *babble plus* *environmental* noise condition. The arithmetic test shows a similar pattern but for the speed of information processing test performance decreases in the babble condition for both numbers of items correct and pages completed. The number of correct answers then decreases further when classroom babble is combined with environmental noise.

***Non-verbal task***

The non-verbal task provided three outcome measures: number of items, number of pages and errors. To explore whether there were statistically significant differences across tasks and conditions we computed a series of univariate analyses of variance. We report effect sizes to show how much variation is accounted for.

Statistical analysis showed that there was a significant effect of noise condition for the non-verbal (speed number of items correct) task, $F(2,158) = 10.352$, $p < .001$, $\eta^2 = .14$. This relationship holds after controlling for both gender and overall ability (as indicated by the ability test also administered). Post hoc Scheffe's tests indicated that children in the *base* condition were scoring significantly better than the children in the *babble* condition ($p < .05$) and the *babble and environmental* noise condition ($p < .001$). There were no significant differences between noise conditions in the numbers of pages completed, $F(2,158) = 1.528$, *ns*; however there was a statistically significant difference in the numbers of items missed, $F(2,151) = 27.467$, $p < .001$, $\eta^2 = .16$. Children missed significantly more items in the *babble and environmental* noise condition than in the *babble* condition ($p < .01$), and significantly more items in the *babble* condition than the *base* condition ($p = .05$). Surprisingly the error pattern was different. The numbers of errors differed significantly between the base condition and the other two noise conditions, $F(2,63) = 6.060$, $p < .01$, $\eta^2 = .16$), more errors being made in the *base* condition than in either the *babble* ($p < .01$) or the *babble and environmental* noise ($p < .005$). However, the numbers of errors in the two latter noise conditions did not differ significantly. Thus the noise conditions did not increase the children's error rate in terms of mistakes but increased the numbers of items they missed resulting in a poorer overall performance since fewer items were completed.

***Verbal tasks***

There was also a significant effect (after controlling for gender and ability) of noise condition on the verbal tasks, both in the case of reading, $F(2,158) = 15.056$, $p < .001$, $\eta^2 = .16$ and spelling, $F(2,158) = 18.1$, $p < .001$, $\eta^2 = .19$. Post hoc Scheffe's tests indicated that for both tests children in the *babble and environmental* noise condition performed better than children in the *base* ($p < .05$) and the *babble* conditions ($p < .001$), and children in the *base* condition performed better ($p < .05$) than children in the *babble* only condition.

***Arithmetic***

Scores on the arithmetic test were similarly affected, $F(2,158) = 5.476$, $p < .005$, $\eta^2 = .07$ with children performing significantly better in the *base* condition than the *babble* ($p < .01$); however in this case performance in the *babble and environmental* condition was not statistically significantly different to that in the *base* or *babble* condition.

***Summary of group results***

Thus children’s performance in the verbal task provided the following pattern of results: *babble<base<babble and environmental*, whereas in the non-verbal task a different pattern of results was evident: *babble and environmental<babble<base*. These results show a complex picture. For the non-verbal task the *base* condition appears to support better performance. In contrast for the verbally mediated task, in this case reading, children perform best in the *babble and environmental* noise condition. A possible explanation is that by chance the children in the two classes that received the *babble and environmental* condition might be more able. This however is unlikely since the relationships hold after controlling for ability (AH4). Rather, the results suggest that the noise conditions affect non-verbal and verbal tasks in a different way. Specifically, on non-verbal tasks children’s performance in noise is compromised with the *babble and environmental* noise condition having the most marked effects. In contrast, performance on the verbal tasks is worst in the *babble* only condition**.**

*The differential impact of noise on children with English as an additional language*

In this section we only consider cases where there was an interaction between noise condition and language status. There was no interaction between language status and noise condition for the AH4, $F(2, 158) = 2.838$, *ns*; reading, $F(2, 158) = 2.576$, *ns*; spelling, $F(2, 158) = 1.870$, *ns*; speed number correct, $F(2, 158) = 2.185$, *ns*; number of incorrect responses, $F(2, 64) = .666$, *ns*; and missed items, $F(2, 152) = 2.974$, *ns*. However, there was a significant interaction between language and condition for the number of pages completed and language status, $F(2, 158) = 4.025$, $p = .02$, $\eta^2 = .05$. A series of univariate analyses of variance indicated that while there were significant differences for the three noise conditions for the native speakers of English, for children with English as an additional language there was no difference between baseline performance and the *babble* condition; however performance in the *babble and environmental* noise was significantly worse than in both *base* and *babble* (p=.05). Thus, EAL children in the current sample did not, on average, experience a differential negative effect of the *babble* condition on this task.

*The differential impact of noise on children with special educational needs*

In contrast to those with English as an additional language, children with special educational needs produced different patterns of results. As Table II shows children with special educational needs, as a group, performed significantly worse on all measures except the non-verbal speed of processing measure.

INSERT TABLE II ABOUT HERE

There was no interaction, between special educational needs and experimental condition for the AH tests overall score, $F(2, 158) = 2.257$, *ns*; the arithmetic test, $F(2, 158) = 1.144$, *ns*; speed items missed, $F(2, 152) = 1.410$, *ns*; and speed incorrect responses, $F(2, 64) = 1.499$, *ns*. However, children with SEN performed differently in the reading and spelling tests; in these two tests there was a significant interaction between noise and special educational needs (reading, $F(2,158) = 4.088$, $p = .02$, $\eta^2 = .05$; spelling, $F(2, 58) = 5.39$, $p = .005$, $\eta^2 = .07$) with the *babble* condition having a particularly detrimental effect on the children with special educational needs. Mean scores for SEN and typically developing children are presented in Table III.

There was also a significant interaction between children's group (SEN or typically developing) and noise condition for the number of pages completed ($F(2, 158) = 3.072$, $p = .049$, $\eta^2 = .04$). A series of univariate analyses of variance indicated that while there were significant differences for the three noise conditions for the typically developing children, for children with special educational needs noise did not significantly alter their performance. A significant interaction was also evident between condition and child group for the speed test number of correct items, $F(2, 158) = 3.372$, $p = .04$, $\eta^2 = .04$. Once again there were significant differences between all three conditions for the children without identified special educational needs (*base>babble>babble and environmental*) at the .05 level but no differences between the three conditions for the children with special educational needs as is shown in Table III. However, in both cases the statistical power is reduced for the children with special educational needs. These interactions in performance are shown in Figure 1.

INSERT FIGURE 1 ABOUT HERE

In summary, while the *babble* condition results in reduced scores overall for reading and spelling, children with special educational needs are more severely affected. Further it appears that the children with special needs do not experience the same detrimental effect due to *babble* alone on performance in the speed of information processing task as the other children do.

The current results suggest that the children with SEN are differentially affected by noise. They are less able to process language in the *babble* condition but less distracted than the other children by *babble* in the nonverbal task.

## Conclusions

The current study aimed to evaluate the impact of different classroom noise conditions on children's performance in literacy, arithmetic and speed of processing tasks. The results indicated that the two different noise conditions had differential effects on the children's performance on verbal and nonverbal tasks. Noise condition accounted for a significant proportion of the variance: 16% for reading and 20% for spelling. Performance on verbal tasks was negatively affected by classroom *babble*, whereas performance on the speed task was reduced in *babble* but further reduced when babble was superimposed with environmental noise. No obvious pattern of additional deficits were evident for children with English as an additional language. However, it is important to note that the observed power was low (.456) and therefore larger sample sizes are needed to conclusively reject the differential hypothesis. In contrast the observed power was acceptable (.998) to detect differences for the children with special educational needs, who were differentially negatively affected on the verbal tasks.

The interference with the verbal task that occurred in the *babble* condition is predicted both by previous laboratory studies of noise effects on performance with adults and children and by current models of information processing. These models suggest that interference by speech directly impacts on working memory by competing with the target verbal material. Both reading and spelling, where the processing of text involves working memory processes, are particularly vulnerable to this effect. The surprising and unpredicted result is the marginally better performance in noise with environmental stimuli. A possible explanation in the current context is that this condition actually encouraged children to actively focus on the task, possibly by redirecting attention. The relatively limited assessment periods may mean that children were able to maintain this high level of attention. Because children's performance was not time- limited there was sufficient scope to refocus on the task at hand. It is unlikely that this added advantage in processing would be evident over more extended exposures to noise (Hughes & Jones, unpublished). This is, however, a testable prediction.

Performance on the nonverbal, time-limited processing task showed the predicted pattern of interference by the distracting *babble* stimulus, and a further reduction in performance with the interference provided by the intermittent noise. The time-limited nature of the task meant that any attempt to redirect attention would reduce the number of items completed. Children did complete fewer items, thereby supporting the prediction. The performance of the children with English as an additional language was not negatively affected by *babble* on this task. It may be that either the children did not attend to the stimulus or the *babble* was not sufficiently meaningful to them to reduce performance. In contrast the children with special educational needs demonstrated no differential effect on performance in this task in the different noise conditions.

Of particular concern is the negative differential effect of *babble* on the children with special educational needs in the verbal tasks. This is particularly worrying given that background noise by other children is the major noise source found in classrooms (Shield & Dockrell, 2004) and current policy aims to educate children in 'inclusive' environments. It is unlikely that this difference can be explained by less focussed attention since these children were not particularly vulnerable in the *babble and environmental* noise condition and performance was not similarly reduced in the nonverbal task. The detrimental effect on the verbal processing task by speech related material is best explained by the children’s difficulties with verbal processing. Children with language, reading and hearing problems are often vulnerable in the area of processing verbal material and this is frequently evidenced in terms of poor phonological skills (Bishop, 1997; Dellatolas *et al.*, 2002; Gilbertson & Kahmi, 1995; Harris & Beech, 1998). The current results indicate that this vulnerability may be exacerbated in acoustically marginal classrooms.

Consideration of classroom acoustics offers scope for both improving learning and providing more inclusive classrooms. It is important that teachers, parents and administrators understand the impact that a noisy classroom has on students’ learning and work with noise control consultants and architects to create a quiet learning environment. Different areas of a school have differing acoustical requirements (DfES, 2004), which depend to some extent on activities, and type of teaching and so on. Reverberation times and potential noise in a classroom can be reduced by the use of acoustic ceiling tiles, wall coverings, and carpets to absorb sound. An acoustical consultant can advise on the acoustic design of a school and on appropriate classroom modifications. In parallel with studies of the effects of noise at school, there have been several surveys of classroom noise and acoustics, and investigations into the way in which the acoustics of classrooms may be improved (Canning & Peacey, 1998). Concern about the effects of noise on children’s learning, and how they may be mitigated, is reflected in current work towards improving standards for classroom acoustics.

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Table I. Performance scores on each test for all children

| | *Base condition* | | *Babble* | | *Babble and environmental* | |
|---|---|---|---|---|---|---|
| | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SD* |
| Reading test (maximum score 75) | 33.45 | 11.62 | 27.59 | 12.23 | 39.48 | 8.95 |
| Spelling test (maximum 15) | 9.55 | 3.89 | 7.18 | 4.59 | 11.68 | 2.75 |
| Arithmetic test (maximum 17) | 8.00 | 2.96 | 6.86 | 2.74 | 8.70 | 2.83 |
| Speed: Number of correct answers (maximum 75) | 44.62 | 21.85 | 37.35 | 16.63 | 30.02 | 9.14 |
| Speed: Number of pages completed (maximum 15) | 12.38 | 10.24 | 9.12 | 5.39 | 10.11 | 12.19 |

Table II. Performance of children with SENs and typical peers on assessments across noise conditions

| | | Typical children | | Children with special educational needs | | ANOVA DF 1, 157 in all cases | |
|---|---|---|---|---|---|---|---|
| | | *Mean* | *SD* | *Mean* | *SD* | *F value* | *p<* |
| Aptitude | AH1 overall | 22.56 | 6.59 | 17.84 | 6.09 | 15.325 | .001 |
| Verbal | Reading test | 35.55 | 10.74 | 27.84 | 13.65 | 12.959 | .001 |
| | Spelling | 10.08 | 3.83 | 7.84 | 4.81 | 8.684 | .01 |
| Numeracy | Arithmetic test | 8.20 | 2.94 | 6.89 | 2.66 | 5.924 | .05 |
| Non-verbal | Speed-number correct | 38.69 | 18.02 | 33.21 | 16.26 | 2.793 | *ns* =.097 |
| | Speed-number pages | 10.72 | 9.02 | 10.18 | 12.24 | .087 | *ns*=.769 |

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Table III. Performance on reading and spelling by children in three conditions

| | | *Base condition* | | *Babble* | | *Babble and environmental* | |
|---|---|---|---|---|---|---|---|
| | | *Mean* | *Standard error* | *Mean* | *Standard error* | *Mean* | *Standard error* |
| Reading | SEN | 28.00 | 2.60 | 13.44 | 3.40 | 36.93 | 2.7 |
| | Typical | 35.50 | 1.61 | 30.76 | 1.61 | 40.36 | 1.61 |
| Spelling | SEN | 7.80 | .91 | 2.33 | 1.18 | 11.43 | .94 |
| | Typical | 10.20 | .56 | 8.28 | .56 | 11.78 | .56 |
| Speed: number correct | SEN | 32.40 | 4.28 | 39.00 | 5.43 | 30.36 | 4.36 |
| | Typical | 49.20 | 2.58 | 36.96 | 2.57 | 20.90 | 2.58 |

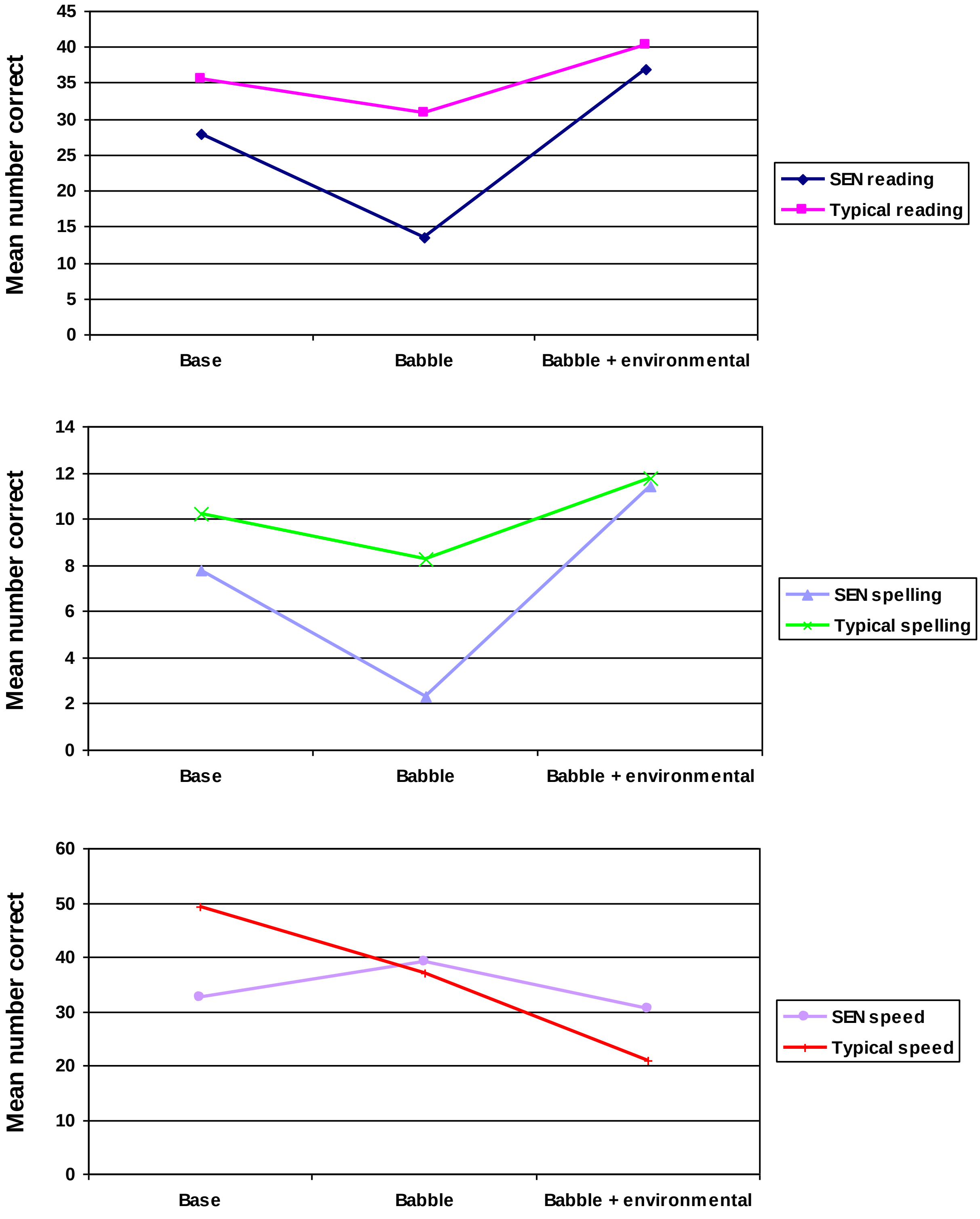


Figure 1. Interactions of noise condition and learning needs for reading, spelling and speed of information processing.