THE IMPACT OF CLASSROOM NOISE ON READING COMPREHENSION OF SECONDARY SCHOOL PUPILS

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1 INTRODUCTION

It has been known for many years that poor acoustic conditions in classrooms leading to high noise levels and poor speech intelligibility cause annoyance to pupils and teachers and affect the academic performance of pupils. Much of the previous research concerning the impact of noise and poor acoustics on pupils has involved children in primary schools, with fewer studies related to pupils of secondary school age. Furthermore, the majority of previous studies in schools have examined the impact of environmental noise, particularly aircraft noise, on children. The aim of the study described here was to examine the effects of typical levels of classroom noise on secondary school pupils, and to attempt to identify the threshold level at which adverse impacts might occur.

A survey of acoustic conditions in secondary schools in England[1] was accompanied by questionnaire surveys of pupils to ascertain levels of annoyance caused by noise, and their perceptions of its interference with their ability to hear and understand their teachers[2]. In addition, students were tested in numeracy, mathematical reasoning, memory and reading comprehension in different levels of classroom noise. This paper describes the results of reading comprehension tests undertaken by nearly 1000 pupils aged between 11 and 16 years while they were exposed to typical classroom noise at different levels.

2 BACKGROUND

Many studies have shown that excessive noise at school causes annoyance and disturbance to pupils[2-6]. Pupils are aware of the disruptive effects of noise, including its interference with hearing the teacher and with concentration, and high levels of disturbance and annoyance have been reported by pupils in both primary and secondary schools. One of the most disturbing noises reported by pupils is that of other students talking, both within and from outside their classroom[2,5,6].

Previous research has also established that both environmental and classroom noise affect pupils' performance in subjects such as reading and mathematics, as well as in memory tasks[7-12]. In particular, there have been several large scale studies in recent years examining the impact of aircraft noise on reading[8,10,13]. Most of this research has involved children in primary schools, and has shown that pupils in schools exposed to high levels of aircraft noise experience a delay in reading development[8,10,12,13].

There have been fewer studies of the effects of classroom noise. An examination of the effect of classroom 'babble' on primary school pupils showed that their performance in tests of reading, spelling, arithmetic and speed of processing was negatively affected when exposed to typically levels of classroom noise[14]. Studies with high school pupils have found negative effects of speech-like noise and road traffic noise on recall of text[15] and of background white noise on free recall of visually presented sentences[16].

By the time pupils enter secondary school, much of teaching and learning occurs through written text in the form of books, worksheets, online material or instructions. Thus, it is important to understand the factors that might negatively impact on pupils' speed and accuracy of accessing written materials. The current study was therefore designed to examine the effects of internal classroom noise, primarily classroom chatter, at different levels on the ability of secondary school pupils to comprehend and learn from written texts.

It is known from both laboratory and field studies that unattended speech and speech-like sounds affect understanding, attention and verbal short-term memory processes in adults, a phenomenon known as the irrelevant sound effect (ISE)[17,18]. Recent studies suggest that children may also be subject to similar effects caused by the ISE[12,19,20]. The relationship between these cognitive processes and reading comprehension is unclear but the disruption of encoding and recall of information by background noise, especially when speech-like, is reflected in impaired reading comprehension by adults in noisy conditions, with ISE causing the greatest disruption[21].

3 SURVEY OF LESSON NOISE LEVELS

Acoustic and noise surveys were undertaken in 13 schools in England, in a range of rural, suburban and urban locations[1]. Noise levels were measured in 185 unoccupied spaces and during 274 lessons in core subjects (mathematics, English, modern foreign languages, humanities and science) in 80 classrooms. Noise levels recorded during teaching ranged from 45 to 76 dB L_{Aeq}, with an overall average level of 64.2 dB L_{Aeq}[1]. A histogram of the lesson noise levels measured (dB L_{Aeq}) is shown in Figure 1.

The levels measured are consistent with those found in other surveys of occupied classrooms in secondary schools[4,6,22].

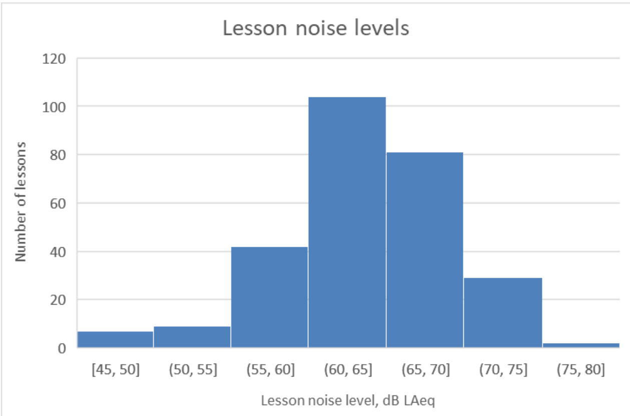

Figure 1. Histogram of equivalent continuous noise levels measured during 274 secondary school lessons

4 READING TEST

The reading test described here was part of a test battery that also included tests of numeracy, speed of processing and short term memory. The tests were presented to the pupils on individual laptops, with typical classroom noise being playing on headphones at levels that reflected the range of noise levels measured in the secondary school noise survey described in Section 3.

Each participant completed the reading task in two noise conditions on two separate testing sessions two weeks apart, on the same day of the week and at the same time. Half the participants did the test in the quieter condition first while the other half had the louder condition first. This was in order to control for any possible influence on performance on the second test of having already done the test once.

4.1 Reading test materials

The test consisted of participants reading a bespoke science text created from scientific news articles. Comprehension and word learning were assessed by multiple choice questions, and the times taken to read the text and to answer each question (response latency) were also recorded.

Two sets of test materials were developed, each consisting of four short articles 180 words in length, and with an average of 1.2 polysyllabic words per sentence. The average reading age of the articles was 11 to 12 years. Each article was accompanied by five multiple choice questions assessing factual information contained explicitly in the text (two questions), information that could be inferred from the text (two questions) and learning of a single polysyllabic word contained in the title page of each text (one question).

4.2 Test procedure

The test sessions took place in the pupils' usual science room under the supervision of a teacher and two researchers. Participants were given verbal instructions prior to the test, and completed an animated tutorial on the laptop.

The four articles were read in a fixed order, from the easiest (reading age 11) to the most difficult (reading age 12). Each article started with a title page featuring a polysyllabic word describing the subject matter of the article, with a definition, for example 'Selenology: The Study of the Moon'. The article was divided into three sections of text, each 60 words in length. Each section was followed by one or two questions that had to be answered before proceeding to the next question. Each article was presented in the following sequence:

- Title page (containing science word to be tested subsequently)
- Text section 1
  - Question 1 (factual)
- Text section 2
  - Question 2 (factual)
  - Question 3 (inferential)
- Text section 3
  - Question 4 (inferential)
- Question 5 (word learning)

When all sections of the article and questions were completed, participants progressed onto the next article. The whole task was time limited to four minutes in total.

Response latencies for all questions and the reading times for each section of text were recorded automatically; timing was commenced when the spacebar was pressed to advance to the item and terminated when it was pressed to advance to the next item.

4.3 Noise stimulus and levels

Two experiments were carried out. In each one the performance of participants in classroom noise level at a level of 50 dB L_{Aeq} was compared with their performance in a higher level of noise; in Experiment 1 the higher level was 64 dB L_{Aeq} and in Experiment 2 was 70 dB L_{Aeq} dB. These levels were chosen following the noise survey of occupied classrooms[1]: as discussed in Section 3, 64 dB dB L_{Aeq} was the average level measured across all lessons, while 50 dB L_{Aeq} and 70 dB L_{Aeq} represented the upper and lower ranges of the levels measured during lessons.

The noise stimulus was constructed from recordings of pupils aged 12 to 13 years as they engaged in individual work in a cellular classroom. The recordings consisted of unidentifiable speech (babble) and sound events (for example, chair scrapes, pencil drops, movement). Eight unique but acoustically identical segments of recording were combined to create a noise stimulus with a total duration of 4 minutes 40 seconds. Filters were applied to the signal to correct for the frequency response of the headphones and ensure that calibrated dB levels were reproduced faithfully.

4.4 Participants

A total of 976 pupils, aged 11 to 16, from eight schools participated in the study, 669 from five schools in Experiment 1 and 307 from three schools in Experiment 2. For the analysis of results, and to examine the impact of noise on pupils of different ages, the participants were divided into two age groups: 11 to 13 years and 14 to 16 years. The numbers in each age group for the two experiments are shown in Table 1.

Table 1. Numbers and ages of pupils in Experiments 1 and 2

Age years	Experiment 1		Experiment 2	
	N	**Mean age (sd)**	**N**	**Mean age (sd)**
11 - 13	361	12.14 (0.76)	203	11.98 (0.59)
14 - 16	308	14.75 (0.78)	104	14.33 (0.47)
All	669	13.34 (1.50)	307	12.78 (1.24)

4.5 Data analysis

The number of correct responses for each question type was calculated for each pupil. Performance for all questions was assessed using the number of correct responses for each question type, averaged across all pupils. Mean article reading times were calculated by averaging participants' time to read the 60-word sections of text in milliseconds, each section being timed from the point at which participants cued the presentation of the text to the point at which they cued the presentation of the subsequent questions. The total number of sections to be averaged depended on the speed with which individual pupils progressed through the task.

Response latencies for correct answers only were considered. To prevent data attrition, randomly missing data points were replaced with the mean of the nearest two data points. Mean latencies for each type of question and article reading times were logarithmically transformed to correct for violations of assumptions of normality.

5 RESULTS

The results of Experiments 1 and 2 are shown in Tables 2 and 3 respectively. The tables give the average results for each age group and overall. The numbers of questions attempted, the accuracy of the different types of question, reading times and response latencies are shown for each experiment. (Note that the figures given for reading times and response latencies are logarithmic transformations of the actual times.)

5.1 Experiment 1: comparison of performance in 50 dB L_{Aeq} and 70 dB L_{Aeq}

It can be seen from Table 2 that, considering all students, more questions were attempted in the 50 dB L_{Aeq} noise condition than in the 70 dB L_{Aeq} condition, and accuracy on all question types was greater in the lower noise level. Comparing the performances of the two age groups, it can be seen that although the older age group attempted more questions and obtained more correct answers than the younger group in both conditions, as would be expected, the higher noise level had more of an impact on their performance than on that of the younger age group. The reductions in the number of questions attempted and accuracy on factual and inferential questions in the higher noise levels compared with the lower, were greater for the older age group than the younger.

Reading times were shorter for all pupils and for both age groups separately in the higher noise levels (although differences were not statistically significant). Averaged over all pupils, response latencies were shorter in the higher noise condition, that is participants were quicker to respond in the louder condition. However, the change in noise level had little effect on the response times of the older pupils, it was the younger age group whose response times were affected by the increase in noise level.

The effect of the order of noise conditions in which pupils did the test was examined. Overall, the results were independent of the order of testing although there was an indication that, for the older pupils only, completing the task in the quieter condition first resulted in more attempts to answer in the louder condition.

Thus the results of Experiment 1 show that classroom noise at a level of 70 dB L_{Aeq} has a significant impact upon reading comprehension for all pupils. Performance on all types of question was less accurate at 70 dB L_{Aeq} than at 50 dB L_{Aeq}, the difference being statistically significant for factual and word learning questions. Time taken to read and process the information was also affected by the level of classroom noise: there was a consistent trend for response latencies to be longer in the 50 dB condition for both the inferential and word learning questions, but the effect was only significant for the word learning questions. There was a difference in the impact of noise between the two age groups: the accuracy of the older age group was more affected by the louder level than that of the younger group, whereas reading times and response latencies were longer in the quiet condition for the younger but not the older age group. The order of the noise conditions did not affect the overall pattern of the results.

5.2 Experiment 2: comparison of performance in 50 dB L_{Aeq} and 64 dB L_{Aeq}

Table 3 shows that, as would be expected, and as in Experiment 1, the older age group performed better in general than the younger group in both conditions, with more questions attempted and greater accuracy. However, differences in performance between the two noise conditions are not as clear cut as in Experiment 1. Over all pupils, the noise condition had a statistically significant effect on the number of questions attempted, with more questions being attempted in the 50 dB L_{Aeq} condition.

Table 3 shows that the higher noise level of 64 dB L_{Aeq} affected the performance of the older pupils more than that of the younger ones whose accuracy and number of questions attempted increased in the higher noise level. The accuracy of the older pupils decreased for all question types, and their article reading times and response latency for factual questions increased in 64 dB L_{Aeq}, compared with 50 dB L_{Aeq}. Thus, whereas reading and response times for the older age group were shorter than those of the younger group in the lower noise level, at the higher level they were the same as those of the younger pupils.

6 DISCUSSION

This study has examined the impact of classroom noise of different levels on the performance of pupils of secondary school age on reading tasks. Performance in levels of 64 dB L_{Aeq} and 70 dB L_{Aeq} were compared with performance in noise at 50 dB L_{Aeq}, and the effects on pupils aged between 11 and 16 years were examined. The results showed that both of the higher levels of noise negatively affected pupils' performance, when compared with performance at the lower level of 50 dB L_{Aeq}.

At both 64 dB L_{Aeq} and 70 dB L_{Aeq}, the noise had a considerably greater impact upon the performance of the older pupils, in terms of both the number of questions answered and the accuracy of responses.

The higher noise levels also affected processing times, as represented by reading and response times. Over all pupils, reading times and response times were shorter in the higher noise level in both experiments, suggesting a possible speed/accuracy trade off. However, this effect was greater for the younger age group. Response latencies for the older group were generally the same in the lower and higher noise levels in both experiments whereas for the younger group they were longer in the lower noise level. The longer reading times and response latencies at 50 dB L_{Aeq} suggests that participants were thereby provided with greater processing capacity to facilitate a range of reading strategies. Such strategies might include reading more slowly and carefully, re-reading difficult passages or unfamiliar words, and pausing to reflect and make appropriate inferences.

The greater susceptibility of the older pupils to the effects of noise is consistent with their responses to a survey of adolescents' perceptions of their school's acoustic environment in which the older pupils expressed more sensitivity to noise and its negative consequences[2]. It is also possible that older pupils were more engaged with the task and therefore more influenced by the noise distraction.

The levels at which the noise was presented in the experiments represented typical levels of classroom noise measured in secondary school surveys[1,4,6,22]. The level of 64 dB L_{Aeq} was the average level measured in an extensive noise survey of lessons in secondary schools[1], in which over 10% of lessons gave rise to noise levels greater than 70 dB L_{Aeq} The findings of the study showing the negative impact of classroom noise at these levels is therefore of concern, and highlights the importance of providing an acoustic environment which will facilitate the processes involved in reading comprehension.

The threshold level at which detrimental effects of classroom noise on reading occur are still unknown but the results presented here suggest that they may occur at levels below 64 dB L_{Aeq}. Thus, the noise level during lessons should not exceed this level as a maximum. The secondary school noise survey by Shield *et al*[1] found that there was a significant correlation between lesson noise levels and unoccupied ambient levels. The scatter diagram and trend line relating occupied and unoccupied noise levels are shown in Figure 2. (Note that the unoccupied ambient noise level (UANL) was an approximation of the indoor ambient noise level (IANL) as defined in Building Bulletin 93 (BB93)). The unoccupied level corresponding to 64 dB L_{Aeq} is 34 dB L_{Aeq}. The maximum IANL required for unoccupied classrooms under the current UK regulations, as specified in BB93[23], is 35 dB L_{Aeq}. Thus schools must be designed to meet current standards as a minimum, to ensure that noise levels do not exceed those known to have a detrimental effect upon pupils' reading comprehension.

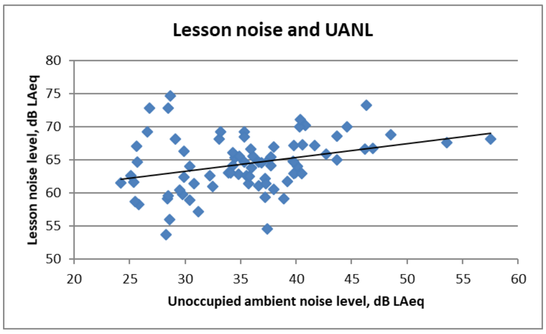

Figure 2. Relationship between occupied and unoccupied classroom noise levels[1]

7 CONCLUSIONS

This study has provided further evidence that the reading comprehension of adolescent learners is negatively impacted by high levels of classroom noise. Pupils aged 14 to 16 appear to be more affected by noise than pupils in the 11 to 13 age range. Classroom noise at levels of both 64 dB L_{Aeq} and 70 dB L_{Aeq} has a detrimental impact upon pupils' performance. Of particular concern is the reduction in performance found when pupils are working in a level of 64 dB L_{Aeq}, as this was the average level of noise measured during secondary school lessons in England. It is also the level of lesson noise which corresponds to the current performance standard for unoccupied indoor noise levels in secondary school classrooms. Thus the study emphasises the importance of both designing the acoustic environment in schools to comply with current standards, and also ensuring that new school buildings meet the required performance standards when they are built.

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Table 2. Results of Experiment 1: means and standard deviations of number of questions attempted, correct answers and log-transformed time-based measures

	Question type	Age group	Noise condition			
			50 dB		70 dB	
			Mean	sd	Mean	sd
Number of questions attempted		11 – 13	11.44	2.25	11.15	3.44
		14 – 16	12.20	2.57	11.55	3.02
		All*	11.85	2.45	11.31	3.28
Accuracy	Factual	11 – 13	2.59	1.26	2.73	1.36
		14 – 16	3.52	1.38	2.86	1.18
		All**	3.10	1.40	2.78	1.29
	Inferential	11 – 13	1.84	1.27	1.81	1.34
		14 – 16	2.38	1.31	2.30	1.27
		All	2.13	1.32	2.01	1.33
	Word Learning	11 – 13	0.93	0.78	0.80	0.75
		14 – 16	1.20	0.76	1.09	0.77
		All*	1.08	0.78	0.92	0.77
Article Reading Time		11 – 13	1.30	0.22	1.23	0.34
		14 – 16	1.27	0.19	1.26	0.23
		All	1.29	0.21	1.24	0.30
Response Latencies	Factual	11 – 13	3.85	0.21	3.82	0.29
		14 – 16	3.79	0.18	3.79	0.19
		All	3.82	0.20	3.81	0.25
	Inferential	11 – 13	3.92	0.21	3.86	0.29
		14 – 16	3.90	0.21	3.90	0.25
		All	3.91	0.21	3.88	0.27
	Word Learning	11 – 13	3.88	0.20	3.80	0.20
		14 – 16	3.73	0.22	3.72	0.19
		All***	3.80	0.22	3.77	0.20

Statistical significance: * $p < 0.05$; ** $p = 0.01$; *** $p = 0.005$

Table 3. Results of Experiment 2: means and standard deviations of number of questions attempted, correct answers and log-transformed time-based measures

	Question type	Age group	Noise condition			
			50 dB		64 dB	
			Mean	sd	Mean	sd
Number of questions attempted		11 – 13	11.16	2.10	11.48	2.87
		14 – 16	13.18	3.20	11.67	2.59
		All*	11.64	2.54	11.57	2.74
Accuracy	Factual	11 – 13	3.14	1.28	3.64	1.38
		14 – 16	3.95	1.37	3.63	1.49
		All	3.32	1.34	3.64	1.43
	Inferential	11 – 13	2.08	1.06	2.35	1.26
		14 – 16	2.95	1.31	2.56	1.31
		All	2.29	1.17	2.45	1.29
	Word Learning	11 – 13	1.00	0.76	1.30	0.85
		14 – 16	1.55	0.69	1.16	0.90
		All	1.13	0.78	1.24	0.87
Article Reading Time		11 – 13	1.33	0.14	1.28	0.13
		14 – 16	1.21	0.19	1.28	0.14
		All	1.30	0.16	1.28	0.13
Response Latencies	Factual	11 – 13	3.82	0.18	3.82	0.15
		14 – 16	3.74	0.09	3.78	0.13
		All	3.80	0.16	3.80	0.14
	Inferential	11 – 13	3.95	0.20	3.92	0.17
		14 – 16	3.86	0.12	3.85	0.13
		All*	3.93	0.19	3.89	0.16
	Word Learning	11 – 13	3.81	0.19	3.77	0.18
		14 – 16	3.73	0.15	3.71	0.13
		All	3.79	0.18	3.74	0.16

Statistical significance: *$p = 0.04$