THE EFFECT OF ACUTE NOISE EXPOSURE ON CHILDREN'S PROCESSING OF VERBAL AND NON-VERBAL TASKS

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Dockrell, Julie[1] and Shield, Bridget [2]

[1] London Institute of Education, 25 Woburn Square, London WC1, UK
Tel: 0044 20 7612 6297, Fax: 0044 20 7684 1051, email: j.dockrell@ioe.ac.uk

[2] School of Engineering, South Bank University, Borough Road, London SE1 0AA, UK
Tel: 0044 20 7815 7658, Fax: 0044 20 7815 7658 email: shieldbm@sbu.ac.uk

ABSTRACT

A study has been carried out to investigate the ways in which different irrelevant sound sources interfere with children's processing of verbal and non-verbal tasks. Around 160 eight-year-old children took part in experimental testing in three different noise conditions, which were based upon the results of internal and external noise and questionnaire surveys in schools. This paper describes the results of the testing and examines the effects of noise on a verbal (reading) and a non-verbal (speed of information processing) task. It was found that noise had an effect on performance but the effect differed according to the nature of the noise and the type of task.

INTRODUCTION

A number of studies have reported that chronic exposure to irrelevant environmental noise can have detrimental effects on children's performance on cognitive tasks. The majority of these studies have considered aircraft noise (Cohen et al., 1980, 1981; Evans et al., 1995, 1998; Evans and Maxwell, 1997; Stansfeld et al., 2000); train noise (Hambrick-Dixon, 1986, 1988), traffic and street noise (Evans et al., 2001; Meiss et al., 2000). The pupils targeted in these studies have generally attended schools near airports, highways, train tracks (Evans and Lepore, 1993, for review). There have been few attempts to reflect performance across different school contexts (but see Evans et al., 2001). Moreover, children are rarely exposed to single sources, although one noise source may indeed be more salient in certain school situations. Yet children are exposed to a wide range of noise sources that vary across school location and classroom position and it is likely that these noise sources interact (Dockrell & Shield, submitted). In particular it has been found that the irrelevant noise that children are exposed to in their classrooms is not solely environmental, but encompasses noise that may be described as 'classroom babble', for example, noise of other children talking in the classroom (Shield and Jeffery, 2001). The kind of irrelevant sound (and the way in which it interacts with other noise) may be a key feature in determining the nature of the interference produced for specific tasks.

This paper describes a study which was designed to investigate the ways in which different irrelevant sound sources interfere with children's processing of verbal and non-verbal tasks. It was predicted that a sound source that was speech based would interfere specifically with the processing of verbal material. In contrast it was predicted that this sound source on its own would have little effect on children's performance on non-verbal tasks. However, a sound source that included random environmental noise in addition to speech was predicted to impact on a non-verbal task that involved serial processing. The present study was complemented by noise and questionnaire surveys of schools and classrooms in London, and parallel examination of the effects of noise on children's performance in standardised assessment tests (Shield and Dockrell, 2002).

METHOD

The experimental study described here involved testing of children on a verbal and a non-verbal task in their classrooms under three different noise conditions.

Participants

Six Year 3 (8 to 9 year old) classes in four different 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 (Shield and Dockrell, 2002). 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. For 83 children their home language was English, 32 had English and another language as their home language, and a further 17 had Turkish as their home language. The remaining children spoke a variety of other languages at home including Portuguese, French, Chinese and Yoruba. Thirty-eight children had some form of special educational need.

Tests

Two tests, one verbal and one non-verbal, were used. In addition all children were given a non-verbal test of general ability. A reading test was used as the verbal measure and a speed of information processing task was used as the non-verbal test.

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.

The speed of information processing test was developed from the British Abilities Scales (BAS) II (Elliott et. al, 1996). The scale assesses how quickly the 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, with 5 items in each page. The test was time limited to 2 minutes. Children recorded their responses by ticking the circle with the most squares in it. The test score was based on both the number of correct responses and the number of pages completed.

Noise conditions

Three different classroom noise conditions were used, thus two classes carried out both tests in each condition. The three noise conditions were derived from the results of the internal and external noise surveys, and the questionnaire responses relating to noise sources heard in the classroom (Dockrell and Shield, 2002). 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 found in classrooms in the classroom noise survey (Shield and Jeffery, 2001). 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 and Shield, 2002, submitted) of children in their classrooms. The noise sources that the children found most annoying were trains (62.4%), motorbikes (60.2%), lorries (58.8%), emergency sirens (57.6%), and helicopters (51%). These sources were therefore 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. Assuming classroom windows to be closed gave an average level inside the classroom due to external noise events of 58 dB(A) L_{Amax}. Although 58 dB(A) is 7 dB(A) below the level of *babble*, the external noise sources were clearly discernible in the *babble*.

Testing procedure

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 the school and that no one else would know their results. Children appeared to enjoy the sessions. The exposure to additional noise 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 thus they should do it as fast as possible without making mistakes.

RESULTS

The children's performances on the tests are presented in Table 1, which shows the means and standard deviations of the scores for each test in the three different noise conditions. (For the speed of information processing both number of correct answers and number of pages completed are presented.)

Table 1 Performance scores on each test

	Base condition		***Babble***		***Babble and environmental***	
	Mean	***Sd***	***Mean***	***sd***	***Mean***	***sd***
Reading test	33.45	11.62	27.59	12.23	39.48	8.95
Speed-number correct	44.62	21.85	37.35	16.63	30.02	9.14
Speed number of pages	12.38	10.24	9.12	5.39	10.11	12.19

It can be seen from Table 1 that in the reading test (verbal task) the performance is worst in the babble condition and best in the babble plus environmental noise condition. For the speed of information processing test performance decreases in the babble condition when both types of score are considered. However, the number of correct answers decreases further when classroom babble is combined with environmental noise.

Statistical analysis showed that there was a significant effect of noise condition for the non-verbal (speed) task children ($F(2,158)=10.352$, $p<.001$). 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 group differences in the number of pages turned over (F (2,158)=1.528, ns).

There was also a significant effect (after controlling for gender and ability) of noise condition on the verbal task (F (2,158)=15.056, p<.001), but in this case the patterns were different to those demonstrated by the results of the non-verbal task. In the Suffolk reading test 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.

These results are summarised in Table 2 which shows where there are statistically significant differences between performance in the different conditions, after controlling for gender and ability.

Table 2 Significant differences between conditions by task after controlling for gender and ability

Test	***Score related to noise condition***		
	Lowest score	***Middle score***	***Highest score***
Reading	Babble	Base	Babble and environmental noise
Speed of information processing	Babble and environmental noise	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 in the *babble and environmental noise* condition are performing the best. 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, especially as the relationships hold after controlling for ability. 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 the noise conditions is compromised with the *babble and environmental noise* condition having the most marked effects. In contrast, performance in the verbal tasks is worst in the *babble* only condition.

DISCUSSION

This study examined the ways in which an irrelevant sound source disrupts the processing of a primary task. The results of the experimental study raise a number of important issues both for the methodology of studies examining the acute and chronic effects of noise (speech and non-speech) and for the development of models to explain the effects of irrelevant noise on cognitive processing.

It was predicted that the effects of acute noise exposure would negatively influence children's task performance. *Babble* was predicted to influence verbal tasks more than non-verbal tasks. It was further predicted that performance under the two different types of noise exposure would vary, with the children who experienced *babble and environmental noise* encountering greater interference than the children in the *babble* only condition. In contrast, the two experimental conditions provided different patterns of effects across the tasks.

The effects of the *babble* alone condition were clearly evident for the verbal tasks. In comparison to the *base* condition the *babble* condition resulted in an overall decrement in performance. Thus, in general the predicted interference with verbal tasks did occur. In contrast to the predictions, performance on the non-verbal task was also significantly impaired in the *babble* condition. Performance in the *babble* condition was significantly worse than performance in the *base* condition for the speed of information processing task (after controlling for ability). This raises the issue of why the *babble* condition has a detrimental effect on the non-verbal task. One possible explanation is that the interference effects are caused by different cognitive mechanisms. Performance on the verbal task may be best explained by an interference with semantic processing due to the competitive phonological information provided in the *babble* condition. In contrast it may be the nature of the non-verbal tasks that dictates the effect. The information-processing task has the additional constraint that the children need to work quickly.

Performance in the *babble and environmental noise* condition shows a dissociation between the tasks. As with the *babble* condition, performance on the non-verbal task was disrupted by this noise condition. Performance is significantly worse than in the *babble* alone condition, indicating that the added unpredictability of the environmental sounds further impairs performance. However, in contrast to the negative effect of the *babble* condition on the verbal task the *babble and environmental noise* conditions improves performance on this measure compared to the *base* and *babble* condition. The inclusion of the environmental noise may diminish the effect of the competing babble by reducing the speech like nature of the stimuli. The fact that these tasks do not involve a serial element and, in fact, on the contrary involve an opportunity for checking suggests that interference is further reduced. By corollary the additional environmental noises could be seen as a means of heightening arousal and increasing performance on the task. Noise can focus attention with cues irrelevant to task performance eliminated. Children in the *babble and environmental noise* condition appear more focused on the verbal task. However, this explanation in terms of arousal does not fit with the results obtained for the non-verbal task.

CONCLUSIONS

In sum, it appears that children are indeed influenced by the presence of acute noise. However, the effect of the noise is determined by the kind of noise and the way in which the noise source interacts with the nature of the task. Consideration of the noise stimuli beyond the sound level in dB or dB(A) is critical. Data reported elsewhere identified the sound from children as the overriding objective noise source in the classroom (Shield and Jeffery, 2001). However, children are aware of environmental noises and their own reported levels of environmental noise are related to objective observations of external noise (Dockrell & Shield, submitted). Thus the noise sources in the present study reflected both a *babble* condition and a *babble + environmental noise* condition. These two conditions had different effects on the children's performance in different test conditions, and showed that the nature of the acute noise exposure differentially influences performance; whether these results generalise to chronic noise exposure requires further consideration.

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