CHILDREN'S PERCEPTIONS OF SPEECH AND HEARING IN OPEN PLAN AND ENCLOSED CLASSROOMS

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1 INTRODUCTION

A questionnaire was developed to investigate children's perception of noise and acoustic conditions in semi-open plan primary classrooms. The main objectives of the questionnaire were to establish the principal sources of background noise experienced in open plan classrooms and to investigate subjective impressions of speech communication for different listening situations (ability to hear teacher, ability to hear peers). Physical classroom design factors investigated as part of the objective survey[1] were also considered to investigate possible differences in responses. The results of the survey have been compared with the responses from a similar subjective study involving enclosed classrooms[2].

2 PROCEDURE

2.1 Design and development of questionnaire

The questionnaires used were based on a questionnaire developed as part of a previous large scale research study (2036 subjects in primary schools in one area of London)[3]. This study investigated precision and consistency of children's responses and showed that children were able to discriminate across classroom conditions in terms of teacher and peer audibility, and that teachers' perceptions were similar to those of the children in their class. Children were also shown to be able to discriminate between different noise sources accurately and report annoyance from these noise sources. The original questionnaire was rigorously tested through two phases of pilot studies (including interviews with teachers and pupils) to construct a valid, reliable and developmentally appropriate tool for use by primary school age children.

2.1.1 Open plan study

The original questionnaire was adapted to investigate noise sources and listening situations specific to open plan environments, including the presence of intrusive speech from teachers and children in adjacent classbases.

The final version of the open plan questionnaire was divided into three sections. Section One gathered personal information (strictly limited to information necessary to investigate research objectives - responses are reported anonymously). Section Two examined the sound sources children were exposed to at school. Children were asked for each sound a) whether they heard the sound b) if they heard the sound source whether they were ever annoyed by it. As in the previous study[3], questions were accompanied by a graphic representation of the sources to contextualise questions followed by a tick box for the children to record their response. Noise sources included 'noise from outside the school', 'musical instruments', 'fans and other machines', 'televisions', 'computers', 'pupils in other class groups', and 'other teachers' voices'. The questions in this section were presented as dichotomous yes-no answers to aid completion by younger children. The section was preceded by a trial question to familiarise the children with the questionnaire and to allow for any problems or questions raised by the children to be addressed.

Section Three examined listening situations across five different contexts. Children rated how well (in general) they could hear what their teacher was saying when their class was quiet and the adjacent classes were:

- Quiet (eg doing a test)
- Working at tables
- Working at tables and moving around the classroom

Children also rated how well (in general) they could hear their peers speaking in the classroom when they were:

- Answering the teacher
- Working in groups

This section used a five point Likert scale (1 - very well, 2 – well, 3 – ok, 4 – not very well, 5 - not at all) transformed into a 'smiley faces' rating scale[3,4]. The question structures of both sections have been shown to be understood by children in the primary school age range (years 2-6) and children's responses to both sections have been shown to be reliable[3,4].

For ten of the twelve schools, children were taken out of the classroom in small groups (10 maximum) during the school day in order to complete the questionnaire. At the beginning of each session, children were briefly introduced to the project followed by a thorough explanation of the questions and the way each answer should be recorded. Children were encouraged to give their own individual answer and assured that their answers would remain confidential. Two classbases consisted of year 1 children. Previous studies had confirmed that the questionnaire was developmentally appropriate for years 2-6, however younger years were not covered. Therefore for this younger group of children, the questionnaire was administered individually to ensure that each child understood the task. For the remaining two schools, the questionnaire was administered by the teacher to every child attending the class during the school day. Teachers were asked to follow the same procedure as described above. The questionnaire was reported to take between 20 and 30 minutes to complete depending on age.

2.1.2 Enclosed study

Although the overall structure of the questionnaire was similar to that used in the open plan study, the questions differed somewhat as a result of the different research objectives for each study. Personal information was gathered in Section One of the questionnaire. Section Two focused on a number of individual external noise sources. Internal sources of classroom noise included musical instruments, televisions, phones and stereos but not speech from children or teachers outside the classroom.

A more comprehensive list of 11 different listening situations were used for Section Three of the questionnaire for the enclosed study. Listening situations which were considered valid for comparison with the open plan study included:

- How well can you hear the teacher when there is no noise outside or inside the classroom?
- How well can you hear the teacher when children are making a noise outside?
- The teacher is asking a question and a classmate replies. How well can you hear your classmate?
- You are working in groups. How well can you hear what your group is saying?

The questionnaires were administered to the pupils in small groups using a similar method to that described in section 2.1.1.

2.2 Participants

For the open plan study, the questionnaire was administered to children in each of the 41 primary school classbases where objective acoustic measurements were made[1]. At least one in three randomly selected children from each classbase participated in the survey (749 children children, 747 valid responses returned). For two of the surveyed schools, questionnaires were given to every child in each participating classroom (488 valid responses). There was a concern that the large number of teacher-administered questionnaires would result in a large number of responses from just two schools, which may bias the results towards a certain design or type of school. To control for possible effects of this, the sample size was controlled by randomly selecting 10 responses from each class (at least one in three) using SPSS analysis software. Checks were carried out on the data to ensure that there was no significant difference between the mean scores and distributions from the randomly selected samples and the whole class sample. This enabled the sample sizes between teacher and researcher administered surveys to be matched. Reponses from 4 classrooms were omitted from the analysis since these classrooms had enclosed elements (eg sliding doors). This resulted in 408 valid responses for analysis.

For the enclosed study, the questionnaire was administered to children in 41 classrooms in 10 primary schools across Hertfordshire, totaling 1008 pupils. Every child in the classroom attending on the day of the survey took part in the questionnaire survey.

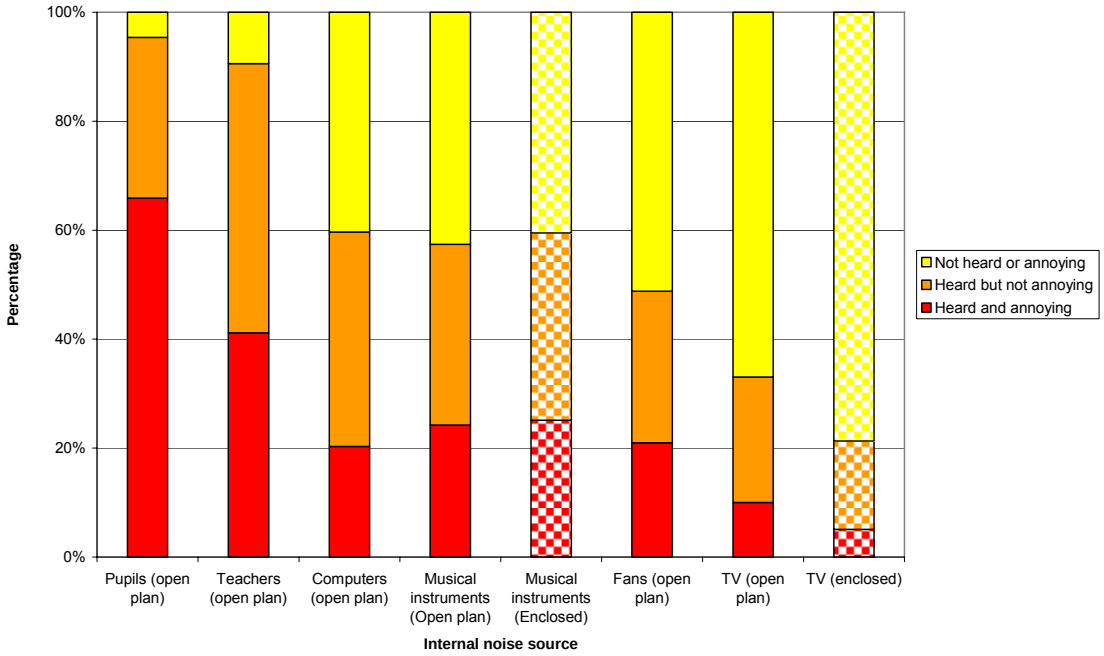
3 RESULTS

3.1 Noise sources

The percentages of children who reported hearing and/or annoyance from external and internal noise sources are shown in figures 1 and 2 respectively. Only limited comparisons may be drawn from the investigations into exposure/annoyance from different noise sources, since each questionnaire focused on different types of noise source. However it is clear that for open plan schools, the most annoying noise source as reported by the largest proportion of children was noise from children in adjacent classbases, followed by other teachers' voices, ie intrusive speech. From inspection it can be seen that for musical instruments, reported hearing and annoyance was fairly similar between enclosed and open plan classrooms, however a larger proportion of children in open plan classrooms reported hearing and being annoyed by televisions. It was not possible to compare reported hearing and annoyance from other internal noise sources directly due to differences between the questionnaire designs.

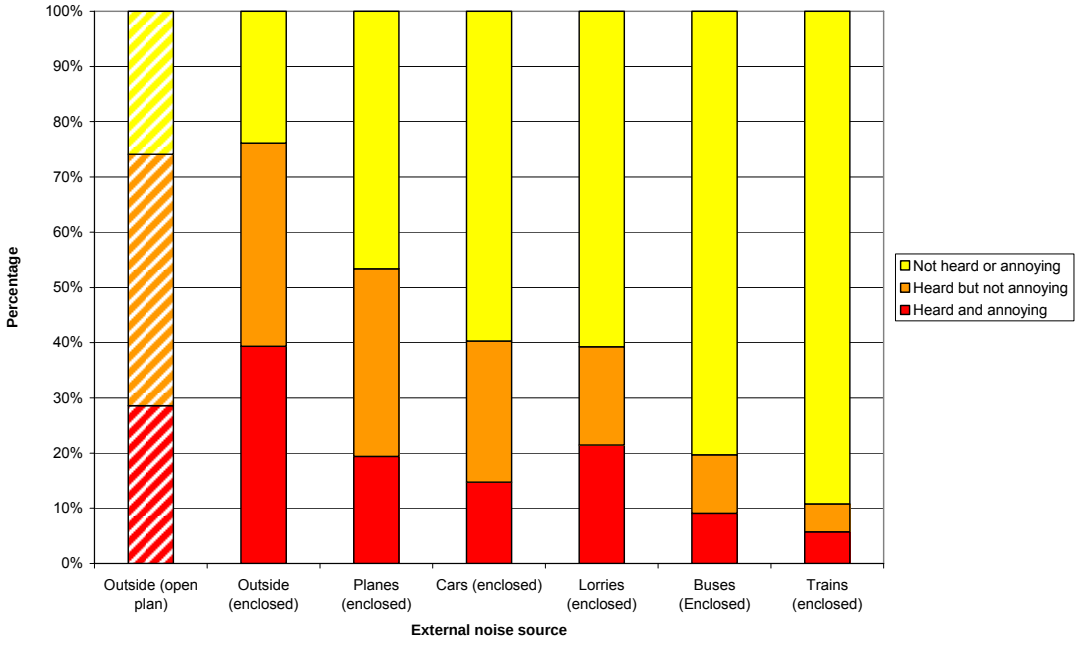
Previous studies into annoyance from noise in open plan offices[5,6] and open plan classrooms[7] investigated acceptable noise conditions in view of the range of individual differences in noise tolerance. These studies proposed that conditions corresponding to 68% acceptability would need to be achieved as a minimum standard (that is, maximum 32% dissatisfaction rate), to ensure that only a minority of individuals is likely to be dissatisfied. Using this criterion, the results suggest that overall, the noise from other pupils and teachers in open plan classbases caused 'unacceptable' levels of annoyance, since over 32% of respondents reported annoyance from these sources. Annoyance from all other sources was reported to be less than 30% overall, suggesting that noise from other sources was satisfactory overall.

Figure 1 Reported hearing/annoyance from internal noise sources



Reported hearing and annoyance from external noise sources is shown in Figure 2. Responses from individual noise sources for the enclosed classroom study were combined in order to make a direct comparison with responses from the open plan study. Whilst there was no significant difference between reported hearing of 'noise from outside the classroom' (χ^2 = 2.724; df = 1; p = 0.099), there was a significant difference between reported annoyance from external noise sources (χ^2 = 11.349; df = 1; p = 0.001), with a larger proportion (>32%) of children in enclosed classrooms reporting annoyance.

Figure 2: Reported hearing/annoyance from external noise sources



3.2 Listening situations

3.2.1 Ability to hear teacher

For open plan classrooms, mean listening scores (1 = 'very well'; 5 = 'not at all') for each listening situation are presented in Table 1. The full rating scale was used by the children. Children's ability to hear the teacher varied with different adjacent activities, with adjacent children 'quiet (eg doing a test' reported as the best listening condition, and children working at tables and moving around the classroom reported as the worst. The results indicate that when activity in adjacent classrooms increases, (and hence intrusive noise level rises), average ability to hear the teacher decreases.

The percentage of children who reported listening scores of '4' (cannot hear teacher very well) or '5' (cannot hear teacher at all) are also reported in Table 1, which may be considered as a dissatisfaction rate. This indicates that overall, according to previous studies[5-7], listening conditions may be considered satisfactory when adjacent classbases were involved in quiet activities and modest activity such as working at tables, but not satisfactory when adjacent classbases were involved in noisier activities including movement around the classroom (dissatisfaction rate > 32%). Further analysis of results is required to investigate additional underlying variables.

Table 1: Mean listening scores & dissatisfaction rates for open plan classrooms

How well can you hear your teacher when your class is quiet and:	N	Mean	σ	% children not hearing very well
Adjacent classes are quiet (eg doing a test)	408	1.7	0.89	3.2
Adjacent classes working at tables	407	2.4	1.04	15.5
Adjacent classes working at tables and moving around classroom	407	3.1	1.15	37.9

For the enclosed classroom study, mean listening scores for each listening situation are presented in Table 2. Since the data were not normally distributed, nonparametric statistical analysis was carried out to test for significant differences between listening scores. A comparison between the two different designs was based on the results of the Mann-Whitney U test using a 95% confidence interval to estimate the significance of the similarities between the populations. A significant difference was found between enclosed and open plan classrooms for when the main classroom and adjacent classrooms were very quiet ($U = 142244.5$, $p < 0.001$), indicating that for this listening situation, average listening scores were significantly better for children in enclosed classrooms (although both designs indicate very low dissatisfaction rates). For the situation when children were making a noise outside the main classroom, only limited comparisons can be made, since the enclosed study did not specify the type of activity noise outside the classroom. However it is apparent that, as for open plan classrooms, average ability to hear the teacher decreases as a result of children making a noise outside the classroom.

Table 2: Mean listening scores & dissatisfaction rates for enclosed classrooms

How well can you hear your teacher when:	N	Mean	σ	% children not hearing very well
Very quiet inside and outside classroom	932	1.3	0.74	2.8
Children are making a noise outside the classroom	933	2.9	1.1	33

2.3.2 Ability to hear peers

Mean listening scores and overall dissatisfaction rates for children's ability to hear their peers are shown in Table 3. No significant difference was found between enclosed and open plan designs for

either listening situation. Dissatisfaction rates indicate that overall ability to hear peers was satisfactory for both open plan and enclosed classrooms.

Table 3: Ability to hear peers – mean listening scores & dissatisfaction rates

	Open plan classrooms		Enclosed classrooms		U-test
Situation:	Mean(σ), n	Dissatisfaction (%)	Mean(σ), n	Dissatisfaction (%)	Sig.
Classmate answer	2.2 (1.06), 409	13.7	2.2 (1.03), 932	11.5	0.543
Working in groups	2.3 (1.23), 407	18.9	2.4 (1.16), 939	18.8	0.360

3.3 Physical open plan design factors

3.3.1 Effect of open plan unit size

Following results of the objective data analysis[1], classbases were categorised by those within 'large' units (more than 3 shared classbases), and those in 'limited' units (3 shared classbases or less).

There was a significant association between unit size and reported frequency of hearing both pupils and teachers in adjacent classbases. Children in large units were significantly more likely to report hearing pupils from other classbases (χ^2 = 5.54; df = 1; p = 0.019), and other teachers voices (χ^2 = 5.408; df = 1; p = 0.020) than children in limited units. Children in larger units were also significantly more likely to report annoyance from other teachers voices (χ^2 = 9.363; df = 1; p = 0.002) than children in limited units. However no significant difference was found between unit size and annoyance from pupils in other classbases.

Children's reported hearing and annoyance from other teacher's voices (figure 3) and other pupils (figure 4) in different sized units is shown below.

Figure 3: Reported hearing/annoyance from other teacher's voices

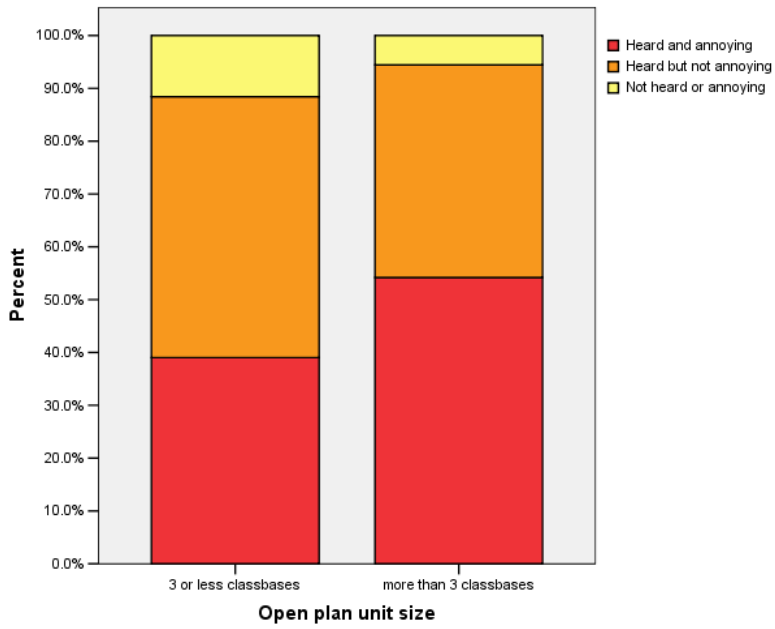
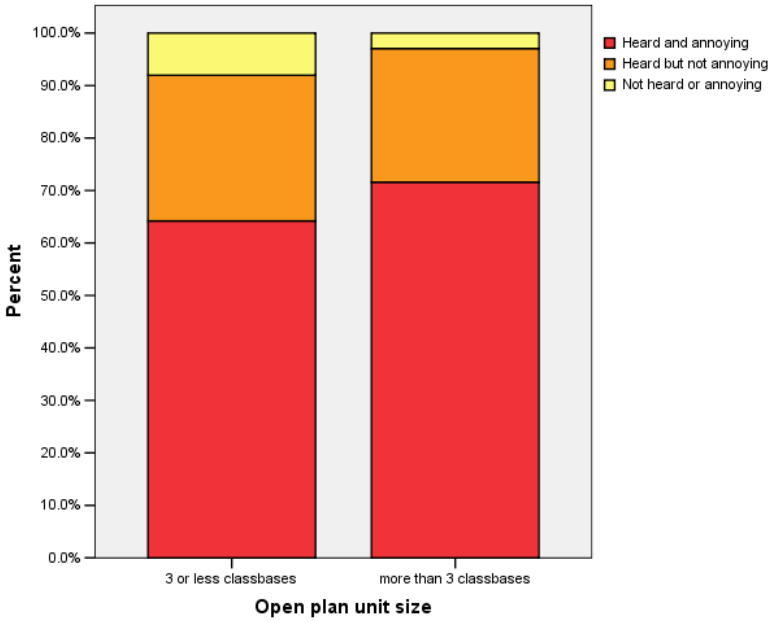


Figure 4: Reported hearing/annoyance from pupils in other classbases



Mean listening scores for the two groups are reported in Table 4. Mean listening scores were generally worse for children in larger units than for those working in limited units. A significant difference was found between limited and larger units for ability to hear the teacher when the adjacent classroom was working and moving around the classroom (U = 19159, p = <0.01), and for ability to hear another child answering the teacher (U = 19329, p = 0.01). No significant difference was found for other listening scenarios.

Dissatisfaction rates between large and limited units were similar when adjacent classbases were quiet, but were significantly greater for larger units with intrusive noise present. Dissatisfaction rates rose to unacceptable levels (> 32%) for larger units for when adjacent activities involved movement, but were at a reasonable level (<32%) for limited units.

Table 4: Mean listening scores & dissatisfaction vs. open plan unit size

	Limited units (n = 168)			Large units (n=268)			
	Mean	Std dev.	% hearing not very well	Mean	Std. dev.	% hearing not very well	p
How well can you hear your teacher when adjacent classes are:							
Quiet (test)	1.62	0.87	3.6	1.67	0.91	3.7	-
Working at tables	2.33	0.96	10.7	2.44	1.08	17.9	-
Working at tables and moving around	2.88	1.15	26.2	3.16	1.11	41.8	0.007
How well can you hear you classmate when:							
They are giving an answer	2.02	1.06	13.1	2.27	1.03	12.8	0.007
You are working in groups	2.25	1.17	13.7	2.31	1.23	20.1	-

3.3.2 Effect of quiet room access

Responses were grouped by children in classrooms with access to quiet rooms, and those without. There was a significant association between quiet room access and reported frequency of hearing other teacher's voices (χ^2 = 17.00; df = 1; p < 0.001). Children in units without quiet rooms were significantly more likely to report hearing other teacher's voices. A significant association was also found between quiet room access and reported annoyance from teachers' voices (χ^2 = 18.00; df = 1; p < 0.001), with children in classrooms without quiet room access being significantly more likely to report annoyance. Children's reported hearing and annoyance from other teacher's voices for the two types of classroom is shown in figure 5 below.

No significant association was found between quiet room access and reported frequency of hearing pupils in adjacent classbases (χ^2 = 1.416; df =1; p = 0.234), or reported annoyance from pupils in other classbases (χ^2 = 2.233; df =1; p = 0.135).

Mean listening scores for children in classrooms with and without access to quiet rooms are reported in Table 5. Mean listening scores were generally lower for children without quiet room access than those with quiet room access. A significant difference was found for ability to hear the teacher when the adjacent classrooms were quiet (U = 15394, p < 0.05) and when adjacent classes were moving around the classroom (U = 14496, p < 0.01). No significant difference was found for other listening scenarios.

Dissatisfaction rates (% children hearing not very well or not at all) were similar when no intrusive noise occurred outside classrooms, but were significantly greater for classbases without quiet room access with intrusive noise present. Dissatisfaction rates rose above 32% for classbases without quiet room access when adjacent activities involved movement, but stayed at a reasonable level (<32%) for classbases with quiet room access.

Figure 5: Reported hearing/annoyance from other teacher's voices

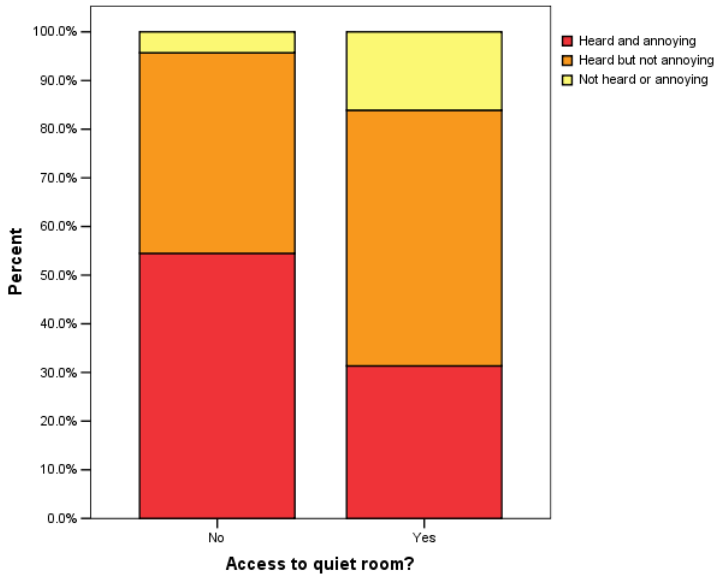


Table 5: Mean listening scores & dissatisfaction vs. quiet room access

	No quiet room access (n=297)			Quiet room access (n=120)			
	Mean	Std dev.	% hearing not very well	Mean	Std. dev.	% hearing not very well	p
How well can you hear your teacher when adjacent classes are:							
Quiet (test)	1.72	0.91	3.4	1.51	0.83	4.2	0.015
Working at tables	2.42	1.03	16.2	2.31	0.99	10.0	-
Working at tables and moving around	3.14	1.12	41.1	2.80	1.11	21.6	0.002
How well can you hear you classmate when:							
They are giving an answer	2.26	1.03	12.7	2.08	1.08	14.2	-
You are working in groups	2.38	1.25	20.9	2.15	1.11	11.7	-

4 DISCUSSION & CONCLUSIONS

The results suggest that children in open plan classrooms generally perceive themselves to be significantly affected by intrusive speech from pupils and teachers in adjacent classbases, in terms of noise annoyance and ability to hear the teacher during critical listening situations. Children's perceived ability to hear their teacher in open plan classrooms decreases as activity in adjacent classrooms increases to involve movement. Results showed that children's perceived ability to hear the teacher in enclosed classrooms was also detrimentally affected by children's noise outside the classroom, although further research would be required to compare directly the extent to which speech communication is affected.

When adjacent classrooms are quiet, children in enclosed classrooms report significantly better listening conditions than in open plan classrooms. Further work is required to investigate possible reasons behind this. However this result should be treated with some caution since slight differences in the wording of the question could result in different interpretation and response. A dedicated study would be necessary to enable a more direct comparison between open plan and enclosed classrooms.

Classroom design (open plan or enclosed) does not appear to significantly affect ability to hear peers, either for a child answering the teacher, or when working in groups. For the group work scenario, the noise climate is likely to be dominated by noise from children in the main classbase itself, and intrusive noise from adjacent open plan classbases is less likely to have an effect.

Although only limited comparisons could be drawn between the sources of noise experienced in open plan and enclosed classrooms, it appears that children in enclosed classrooms are significantly more likely to report annoyance from external noise sources than children in open plan classrooms, even though there was no significant difference between both groups' reported hearing of external noise. Further work would be required to determine why this may be the case, although it is probable that in open plan classrooms, the noise climate is more likely to be dominated by intrusive speech rather than external noise, and so children are less likely to report annoyance from external noise. This result is supported by those of a previous work which compared external noise levels with children's' perceived ability to hear the teacher, and found that external noise levels only affected listening scores when other confounding noise sources such as other children were not present[3].

Results of the open plan study suggest that open plan classroom designs should be limited to three shared classbases in each unit, since pupils are less likely to report hearing teachers and pupils in

adjacent classbases. This is likely to occur simply as a result of lower occupancy levels in the shared unit, and hence lower intrusive noise levels. This type of design is also likely to produce lower dissatisfaction rates in the presence of intrusive activity noise, and significantly higher (and satisfactory) listening scores when adjacent activities involve movement.

Similarly, results suggest that all classbases in the unit should have access to a shared quiet room, since as children are less likely to report hearing and annoyance from other teachers voices, and more likely to report significantly higher and satisfactory listening scores when adjacent activities involve movement.

5 ACKNOWLEDGEMENTS

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