Mitigation of noise in nursery school classrooms by sound absorption: a yearly noise measurement with different absorbing conditions in actual classrooms

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INTRODUCTION

Acoustic environment in nursery schools have been less discussed than those in elementary schools or junior high schools, and, in Japan, there are no standards or guidelines at present for acoustic planning of pre-school classrooms. There are several studies, however, indicating that the acoustic environment in nursery schools can be harmful to physical and mental health of children and teachers. Waye et al. (2010) reported that the average individual exposure level of children was 84 dB (L_{Aeq}) during the active time period in the play hall or kitchen. Grebennikov (2006) pointed out that teachers' exposure level were up to 85 dB (L_{Aeq}) during the six-hour work time. For the mitigation of these noisy situations of the indoor acoustic environment, sound absorption is considered to be a possible solution, and the present study aims to examine this effect. For this purpose, in the previous study (Kawai 2010), we carried out a field experiment in which sound absorbing boards were installed in the classrooms of an actual nursery school, and found the possibility of the effectiveness of sound absorption. In this study, we conducted the second experiment to ensure the evidence with more comparable condition settings.

EXPERIMENT

Installation of sound absorbing boards

A field experiment was carried out in the same nursery school as in the previous study (Kawai 2010) in Kumamoto city, Japan. The school takes care of six classes with children from 0 to 5 years old in the separated nursery room respectively for each year of age. Three different absorbing conditions were set to the six rooms by hanging sound absorbing boards, made of polyester fiber, on the ceilings of the classrooms using nylon strings (Figure 1). Three different absorbing area, namely about 0 (NONE), 40 (HALF) and 80 % (FULL) of the ceiling area, were assigned for each of the six rooms. The experiment period was almost a year from April 2010 to March 2011, as the academic year in Japan begins in April. The whole year was divided into three periods of 2010.4-7, 9-11, 12-2011.3 (August was omitted from this experiment because it was a special period in the school when the classes of from three to five years age were mixed). The classrooms were divided into two groups of the rooms of 0, 2 and 4 year children (R0, R2 and R4) and those of 1, 3 and 5 year children (R1, R3 and R5). In the former group, sound absorption was decreased from FULL to NONE (*Decreasing group*), and that was increased from NONE to FULL in the latter group (*Increasing group*) by each of the periods.

The original surface materials of the classrooms were not apparently sound absorptive with wooden flooring (floor), wooden or gypsum boards (partition wall), glass windows with wooden or aluminum sashes, and gypsum boards (ceiling).

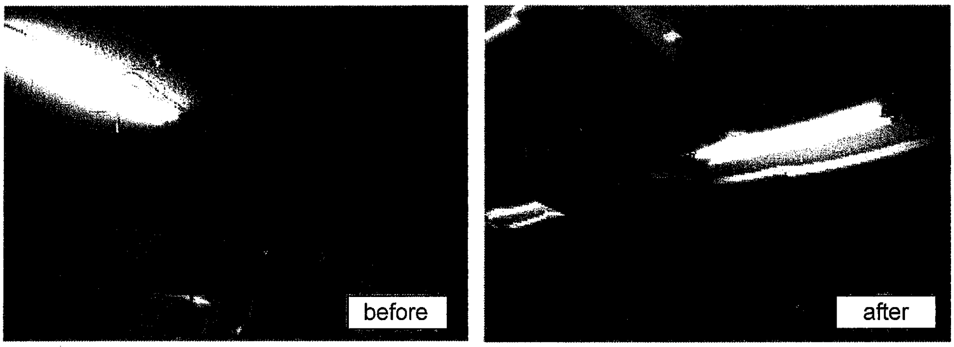

Figure 1: Installation of sound absorbing boards

Acoustic measurement

To obtain the acoustical characteristics of the rooms, impulse responses were measured for each of the rooms using the maximum length sequence (MLS) signals. MLS signals were produced by an omni-directional speaker, received at four points per room, and processed into impulse responses. Reverberation time and RASTI were then calculated from the impulse responses of each of the rooms.

Noise measurement

Indoor sound was recorded in the six rooms to measure the noise levels. Since the sound levels could be affected by the distance between a microphone and sound sources (children), two microphones, both hung 30 cm below the ceiling with several meters apart from each other, were used for recording the sound simultaneously (Figure 2). In order to minimize the effect of the distance-dependent energy of direct sounds from the children, simultaneous sound pressure levels were calculated every 100 millisecond of the two recorded sound sequences and the lower value at every

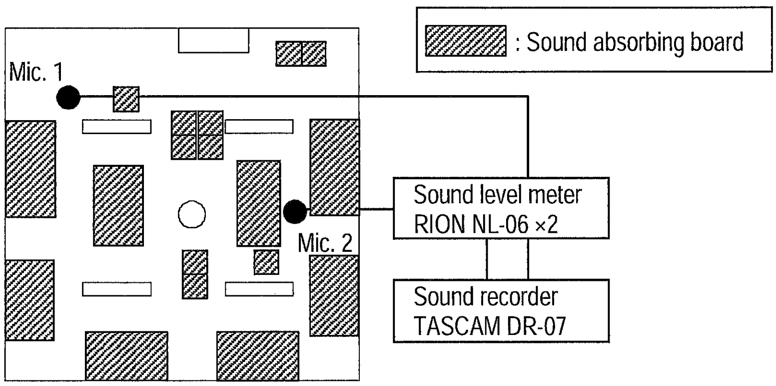

Figure 2: Arrangement of measuring instruments (Ceiling plan example)

Table 1: Dimension and absorbing conditions of classrooms

Room	N of children	Age	W×D×H	V(m^3)	S(m^2)	Absorbing condition in each period (month)		
						Period 1 (4-7)	Period 2 (9-11)	Period 3 (12-3)
R5	21	5	6.0×7.5×3.0	137	173	NONE	HALF	FULL
R4	20	4	6.2×7.5×3.0	141	176	FULL	HALF	NONE
R3	22	3	6.5×6.6×2.4	102	148	NONE	HALF	FULL
R2	25	2	6.6×6.5×2.4	102	148	FULL	HALF	NONE
R1	16	1	5.6×6.6×2.7	99	139	NONE	HALF	FULL
R0	13	0	5.5×6.6×2.7	97	137	FULL	HALF	NONE

moment was chosen. These lower values can be regarded as the sound levels of far from the sound sources and thus can be regard as the levels that represent the energy of diffused sounds rather than that of direct sounds. This also means that the measured SPL is not the exposure level for teachers or children and the values would be considerably lower than the actual exposure levels, as the purpose of this measurement is not to measure the exposure levels but to examine the effect of sound absorption.

Recordings were done for eight hours (9:00-17:00) per day. In the first period, the recordings were done on two or three days just before the condition had changed for the second period, and in the following two periods, the recordings were done once in two week basis. It is needed to select the representative time periods for the analysis of noise level because the levels in classrooms widely varied depending on the children's activity. Thus, three time period were selected: lunch time that was one of the periods in a day when children's voice was loudest, reading time in which the teacher reads a book to the children, and napping time as back ground noises.

RESULTS AND DISCUSSION

Acoustic characteristics

Figure 3 shows an example of the frequency characteristics of children's and teacher's voices recorded in three of the rooms. The children's voices in playing time had its main power in 1 kHz–2 kHz frequency band, and the sound pressure level was higher than teacher's voice. The frequency range of teacher's voice was lower than that of the children with its power mainly in 250 Hz–1 kHz band.

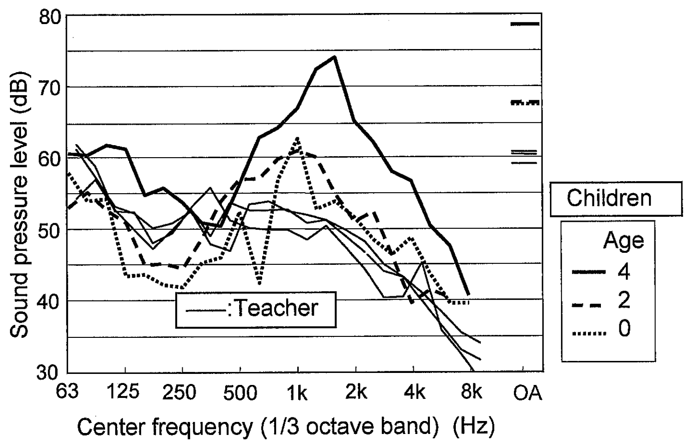

Figure 3: Frequency characteristics of children's and teacher's voices

Figure 4 shows reverberation time (RT) of the rooms with each absorbing conditions. The RT of 1 kHz band without sound absorbing board varied from 0.56 to 0.75 s depending on the rooms that have different ceiling heights and floor areas. Most of these RTs are regarded as too long compared to the recommended value (0.6 s) of WHO environmental noise guideline for the speech intelligibility in classrooms of elementary school and kindergarten (WHO 1999). With the installation of the absorbing boards at 40 % cover ratio (HALF), the RTs of 1 kHz band decreased to 0.39 - 0.42 s, and at 80 % cover ratio (FULL), those were 0.33-0.40 s. RASTI values calculated from the impulse responses were around 0.72 (good) and 0.84 (excellent) before and after the installation, respectively. Average absorption coefficients was then estimated from the RTs using Eyring's formula, and those with 0, 40, and 80 % cover ratio was around 0.16, 0.26, and 0.28 s, respectively, in 1 kHz band in all the rooms.

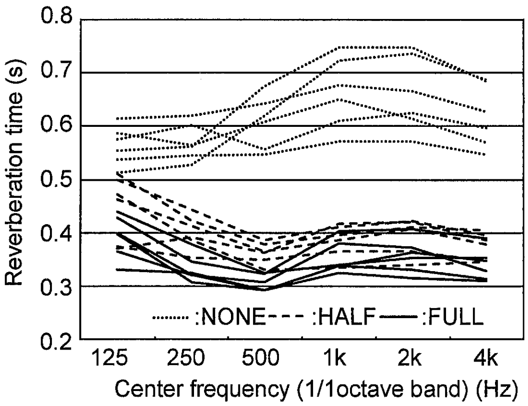

Figure 4: Reverberation time of the rooms with three absorbing conditions

Sound pressure level

The daily sound pressure levels (SPL) measured in the lunch time are shown in Figure 5 and Figure 7. The levels were largely fluctuated but the trend of the noise level was seen generally as in accordance with the increase / decrease of sound absorption. Then the daily noise levels are averaged by each of the absorbing conditions (Figures 6 and 8). In the figure, it is obviously seen that the sound absorption correlated the decrease of noise level.

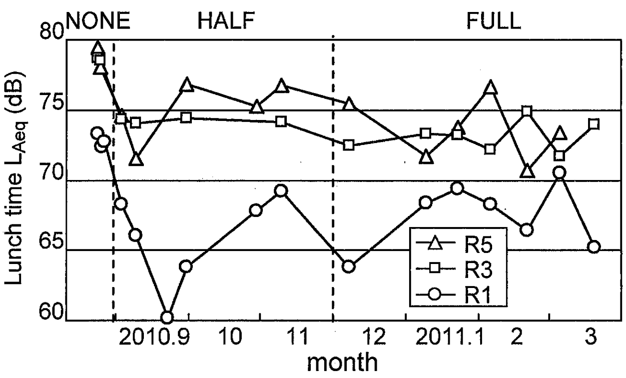

Figure 5: Daily noise level in lunch time (Increasing group)

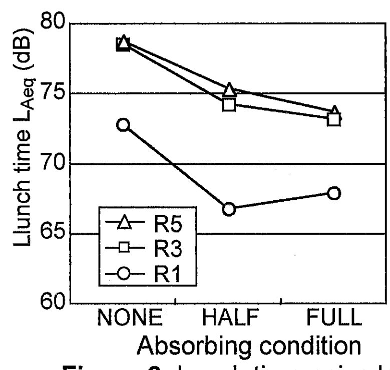

Figure 6: Lunch time noise level averaged by absorbing conditions (Increasing group)

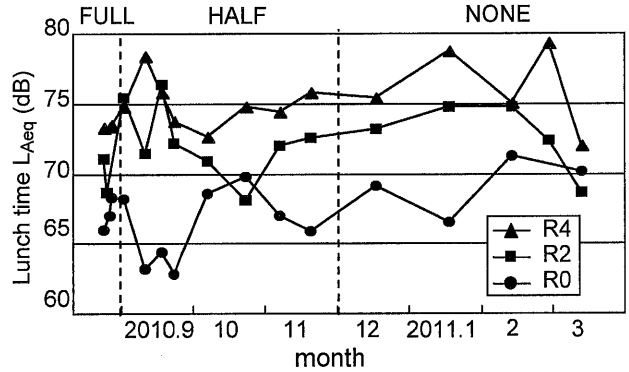

Figure 7: Daily noise level in lunch time (Decreasing group)

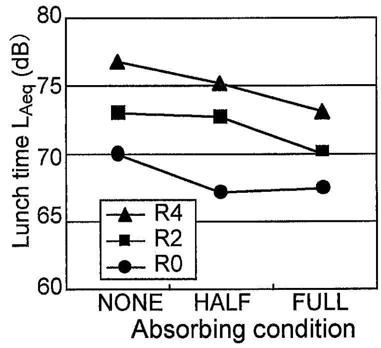

Figure 8: Lunch time noise level averaged by absorbing conditions (Decreasing group)

The average level differences between the conditions of NONE and FULL were 3-6 dB. This difference is greater than the expected physical level reduction by the sound absorbing power (approximately 3 dB assuming diffused sound field) and, therefore, the result suggested that the difference was affected by not only physical reduction but also by the lowered voice levels of the children possibly due to the improved speech intelligibility of the rooms by the sound absorption. The change in dB with the change of absorbing condition was different between *increasing* and *decreasing* groups. When the sound absorption increased NONE to HALF, the level decreased instantly by three to five dB while the change was not so instantly nor obvious when the condition changed from HALF to NONE. A possible reason would be that once the teacher and children were accustomed to less noisy condition created by the sound absorption, they would be accustomed not to make their voices too loud. More evidences are required, however, to ensure these additional effects and it should be obtained though observing the voice levels in further studies.

The reading times L_{Aeq} are shown in Figures 9-12. The levels were even more fluctuated than the children's voice levels in lunch time probably due to the types of books read in the day. Nevertheless, they still showed the change in accordance with the condition of the sound absorption and the averaged level differences between with and without sound absorption were even greater than those in lunch time. We also asked the teachers an open question about the subjective evaluation of the room

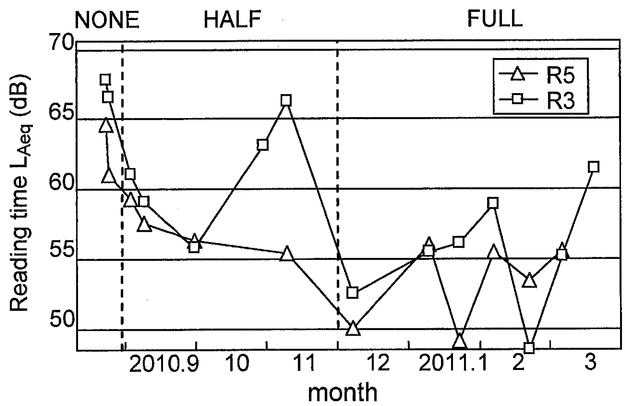

Figure 9: Daily noise level in lunch time (Increasing group)

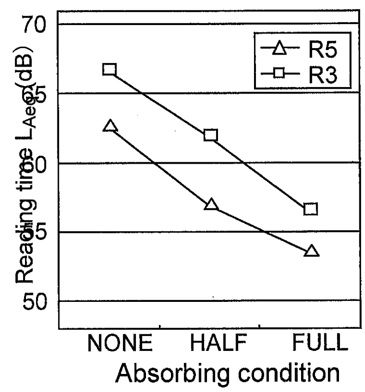

Figure 10: Lunch time Noise level averaged by absorbing conditions (Increasing group)

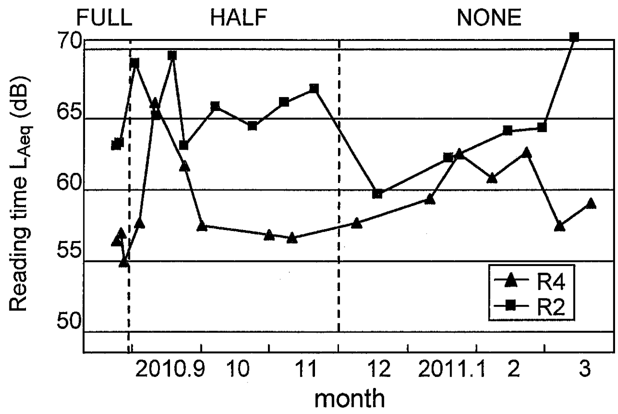

Figure 11: Daily noise level in reading time (Decreasing group)

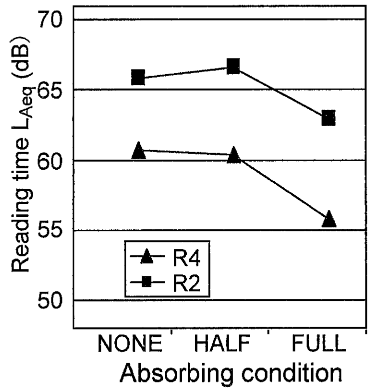

Figure 12: Reading time noise level averaged by absorbing conditions (Decreasing group)

with the sound absorption and found that 9 out of 18 teachers evaluated the sound absorption positively.

CONCLUSIONS

In this study, the effect of sound absorption on the moderation of the noisy acoustic environment of nursery school classrooms was examined through a field study conducted for a year. The result supported the existence of moderating effect of sound absorption on noisy acoustic environment in nursery school classrooms. Further studies are required for accumulating more evidences, in which the exposure level and voice level, activity of children and teachers should be examined.

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