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Effect of sound absorption on children's behavior in daycare rooms: a field experiment with installation of temporary sound absorption.

Keiji KAWAI[1]

[1] Kumamoto University, Japan

ABSTRACT

We have been investigating the effect of sound absorption for children in child daycare rooms and the results demonstrated a mitigating effect of bustling atmosphere in the rooms and an improvement of word intelligibility of children. In this study, we attempt to find behavioral change of children in acoustically absorbed daycare rooms by a field experiment with installation of temporary sound absorption. The experiment was conducted in two actual daycare centers in Kumamoto City, Japan. Three mixed age (3-5 years old) groups in a center were observed during the teacher's announcement in the daily morning meeting and a 1 year old group in another center was observed during being read a picture book by the teacher. The observation was performed with video-recording for 6-10 days and sound absorbing cloths were attached to the ceiling for 2-4 days in the days. The reverberation time without absorptive cloths was 0.65-0.90 s, as the daycare rooms did not have any sound absorptive surface, and it was reduced to 0.4-0.5 s with absorption.
The observation period was 60 second from the beginning of the activity, cut from the recorded video by choosing parts without particular disturbing events such as someone's entering the room. Then the video was divided into 1 second segments and the ratio of the segments in which the face of a child was directed at the teacher was defined as concentration time ratio (CTR). Then the individual CTR was compared by the absorption conditions. The result showed that the CTR of two groups out of four was significantly higher with sound absorption. Though there were several limitations, the result supported the effect of sound absorption.

Keywords: sound absorption, child daycare, concentration, classroom acoustics

1. INTRODUCTION

It is widely recognized that child day-care rooms require optimum acoustic condition as children from 0 to 5 years old are supposed to be in the period of developing their listening and language skill as a WHO guidelines (1) or other political documents (*e.g.*2) state. Several studies examined interference of poor acoustic condition with noises and reverberation on the speech intelligibility of elementary school pupils and found younger pupils were more affected in the poor conditions (3,4). It is highly possible that speech intelligibility of preschool children is more affected by acoustic condition than pupils while we could not find the evidence for this. Thus in the previous study (5,6) we attempted experiences that investigated pre-school children's listening skill under interference of noise and reverberation. The results indicated greater effect of acoustic condition on young children's listening than on that of pupils or adults. Such a loss of speech intelligibility as indicated in the previous studies may cause a loss of concentration of children in verbal communications. Thus in this study, as a further step of investigation of the effect of good acoustic quality by sound absorption on preschool children, a field experiment was performed in which children's listening to teacher's talking in the conditions with and without sound absorption were observed in actual kindergarten classrooms. This paper is a revision of our paper in the proceedings of Internoise 2018 (7) and about a half of the data in this paper came from the same experiment. The procedure of analysis was revised to be more rigorous and reproducible and all the data were re-analyzed.

[1] kkawai@kumamoto-u.ac.jp

2. Experiment

2.1 Experimental rooms

The experiment was carried out in three actual classrooms with the cooperation of two child daycare centers in Kumamoto city region. Dimension of the rooms is shown in Table 1. Room 1 and Room 2 are daily used by three mixed year groups (Group A, B and C) of 3–5 year old children by turns for various kind of activity such as meeting, lunch, free playing, being read picture books by teacher, and so on. Room 3 is a home room of a 1 year old group (Group D). In these rooms, children's concentration in listening to teacher's talking was observed in the conditions with and without temporary installation of sound absorptive materials.

The original surface material of these rooms was not sound-absorptive such as gypsum boards, glass windows or wooden floor, reflecting the situation that sound absorption for children's room is still not popular in Japan. Two reverberation conditions in the experiment were this original condition and that with additional sound absorption by polypropylene fiber cloth with 4.5 mm thickness (Mitsui

Table 1 – Dimensions and acoustic characteristics of rooms for experiment.

Room	Floor area (m^2)	Height (m)	Volume (m^3)	Surface area (m^2)	Absorber area (m^2)	without absorber			with absorber		
						RT (s)†1	STI-1 m	STI-3 m‡2	RT (s)	STI-1 m	STI-3 m
Room 1	141	2.5	352	418	59.4	0.65	0.85	0.74	0.44	0.91	0.82
Room 2	147	2.5	368	418	80.4	0.90	0.82	0.72	0.51	0.91	0.80
Room 3	63	2.6	163	213	41.0	0.73	0.77	0.70	0.39	0.87	0.80

†1 Average over 500-2k Hz band. ‡2 Actually 3.5/3.1/4.0 m in Room1/Room2/Room3, respectively.

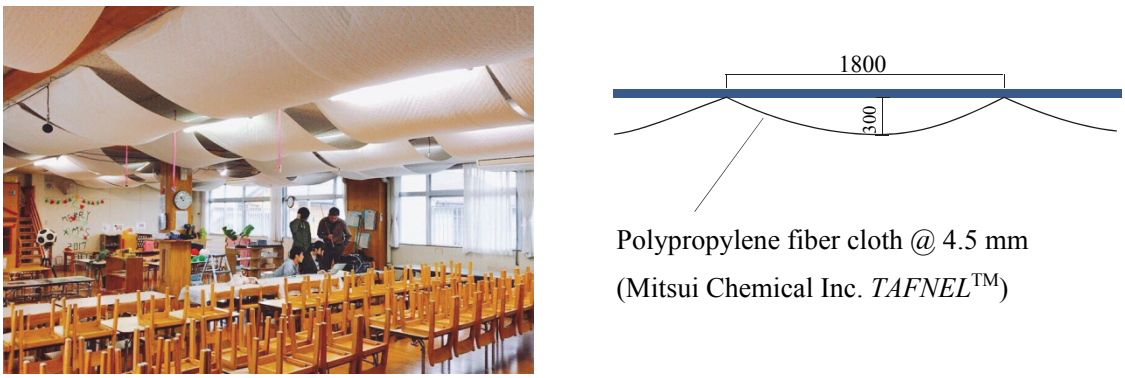

Figure 1 – Attachment of sound absorber

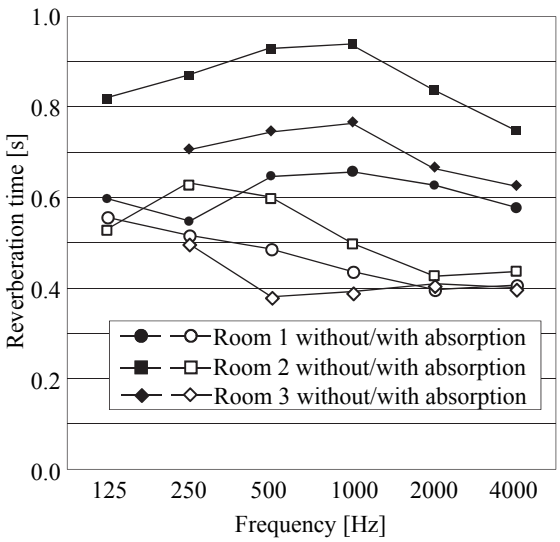

Figure 2 – Reverberation time by installation of sound absorber

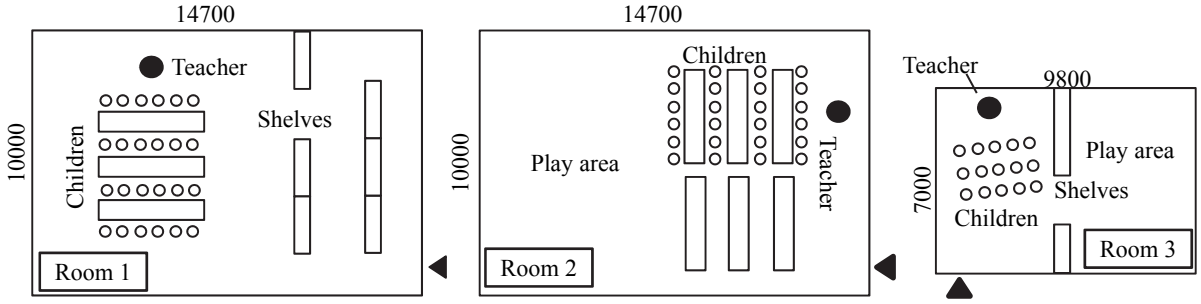

Figure 3 – Layout of rooms for experiment

Chemical Inc. *TAFNEL*™). The cloths were attached on the ceiling with 300 mm back air thickness at the center (Figuge-1). Figure 2 and Table 1 show the reverberation time and STI obtained from impulse response measurements using time stretched pulse method before and after installation of the sound absorbers. The original reverberation time of each room in 500–2000 Hz band was around 0.65 s, 0.90 s and 0.73 s, and the average absorption coefficient estimated by Eyring's formula was 0.20, 0.14 and 0.17, respectively. The short reverberation time in Room 1 was considered to be due to some extent of absorption by the open shelves in which children's personal belongings such as clothes and bags were put. By the installation of the sound absorbers, the reverberation times were reduced to below 0.6 s, which is the target value for playrooms of preschools in the WHO guideline (1), and average absorption coefficient increased to 0.28, 0.24 and 0.31 in Rooms 1, 2 and 3, respectively.

2.2 Behavioral observation

We selected teacher's speeches in morning meetings in Room 1 and Room 2 and those of reading aloud a picture book in Room 3 as target activities for the observation. The morning meeting was held every day and children sat on the chair and listened to the teacher who told them about the activities and schedule of the day. Teacher's reading a picture book aloud to children was performed also every day in the morning as a kind of morning meeting for 1 year old children. The room layout is illustrated in Figure 3.

Each observation time began at the moment the teacher began speaking when everyone became concentrated to the teacher after the teacher calmed the freely playing children by calling them and playing music by an organ and so on. A video camera was set in front of the children and a microphone was hung above the children recorded the activities. Also two experimental staff observed the activities to check any events that might affect children's concentration.

The experiment was carried out from December 2017 to February 2018 in Room 1 and Room 2 and in January and February 2019 in Room 3. Group A, B and C had around 40 children and Group D had 19 children but number of children varied due to absence. The number of children attended and the days with and without sound absorber of each of the groups are shown in Table 2. The number of days of observation were 6-10 and the order of changing absorption conditions differed depending on the groups. The detail is indicated in Table 2 and Figure 4.

There are limitations, as follows, concerning with the quality of the experiment due to the limited possibility of control in the actually running daycare centers and there had to be considered in the analysis. 1) There were two or three homeroom teachers for each groups and the teacher speaking in the meeting changed on the days with and without absorption in the cases of Group A, B and C. This

Table 2 – Sound absorption condition of observation

Group	Number of attended children	Room	Number of observation day	
			with absorber	without absorber
A	27-39	Room 2	2	4
B	28-38	Room 1	3	4
C	26-41	Room 2	4	4
D	11-16	Room 3	3	7

point is considered to be a major flaw of this experiment because the concentration to the speech could be affected by the skill of teachers. This point is discussed later. The teacher of Group D was the same throughout the days. 2) Children were not the same among the days of observation because of absence. 3) Children's attention could be affected by the factors other than acoustics but it was not possible to control actually, and so on.

2.3 Analysis

The observations was performed on the video recordings. The starting point of observation was set at the beginning of the teacher's speech because the teacher had called all the children's attention to him/her at that moment. The observation time period was 60 seconds of the speech for each of the meetings. When an event that interrupted the speech or children's concentration occurred, such as a child of late arrival coming in, the period of interruption was omitted and the 60 seconds were selected from other than interrupted period.

Thus obtained videos of 60 seconds for observation was divided into one second segments and the direction of the face of each of the children was observed by pausing the video play every one second. We judged a child to be concentrated to the speech when his/her face was directed to the teacher, which was due to the quality of the video not enough to observe eye directions precisely. Each of the one second segments was coded into 1: concentrated, 0: not concentrated, x: unable to judge because of the face hidden by other children or other reasons. Then the ratio of the number of 1 to the number of 0+1 was defined as *concentration time ratio* (CTR). The CTR of each of the attended children was analyzed. Since the children sat on different chairs day by day, each of the children on the video was identified over all the days of observation, by the cooperation of the teachers, in order to compare the CTR individually by the change of the absorption conditions.

3. RESULT

As an overview of the result, Figure 4 indicates the individual distribution of CTR by date and the absorption conditions. The CTR distributed widely and the median were 70-95 %. An obvious high CTR by sound absorption was only seen for Group C. It is seen for every group that rather low CTR, such as less than 60%, were relatively fewer with sound absorption than without absorption, while this was statistically significant only for Group C (p=0.003 by chi-square test).

Next, individual CTR was compared between the absorption conditions. Since not many children

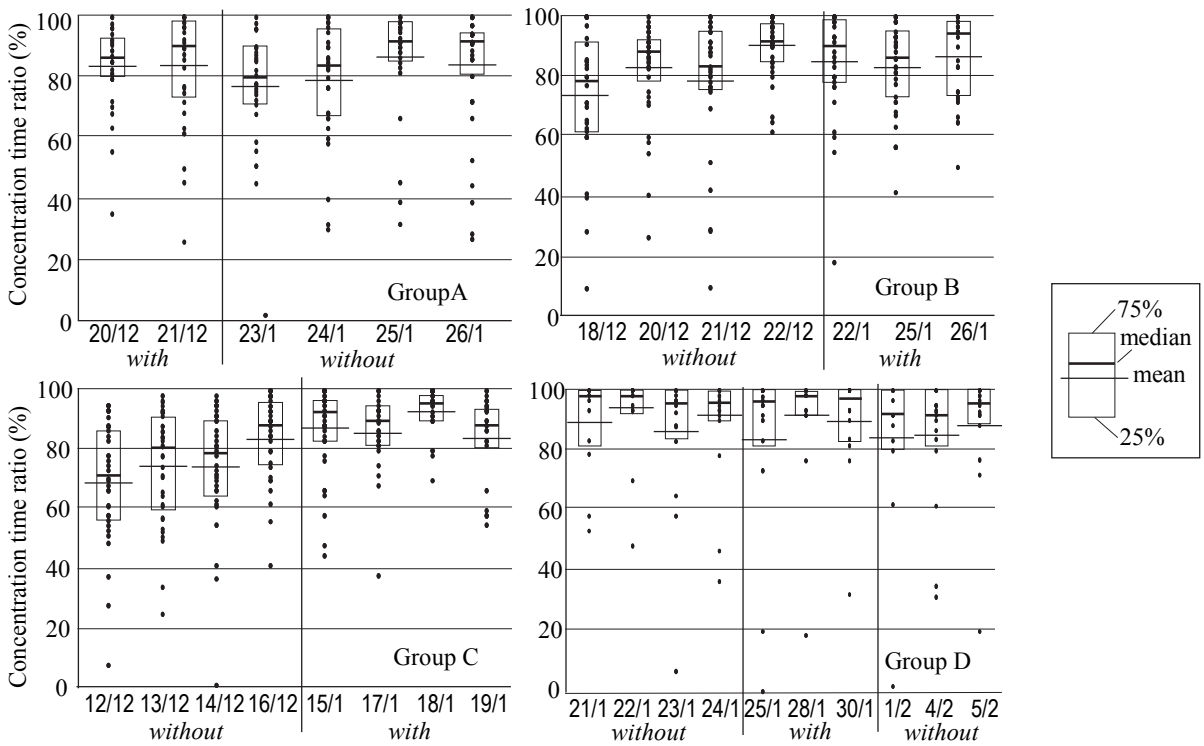

Figure 4 – Individual distribution of concentration time ratio by date and absorption conditions

Table 3 – Binomial test on the effect of sound absorption

Group	N of children who experienced both absorption conditions	N of children indicating better CTR under absorptive condition	Probability of occurrence by binomial distribution assuming equal probability
A	34	21	0.11
B	37	18	0.63
C	41	37	0.00
D	19	14	0.03

attended all the days of observation, the children who experienced both of the absorption conditions at least one day each were selected for the comparison (Table 3). Among them, number of children whose CTR was higher under the condition with sound absorption was counted. Then with a hypothesis that the ratio of these children is expected to be 50 % if there was no effect of sound absorption, the probability of occurrence of actual number of the children of higher CTR with absorption was calculated. The result was that more than 50 % of children other than Group B indicated higher CTR with absorption, with Group C as the highest at 90 %. The probability by binomial test was significantly low for Group C and D, and Group A showed rather low probability of 0.11. The result of Group B with no difference between the absorption conditions might be reasoned by that the meeting of Group B was held in Room 1 with relatively low reverberation originally.

As mentioned before, the teacher of each of Group A, B and C was different between the absorption conditions and therefore an interpretation of the result that these differences came from the different communication skill of the teachers can not be rejected. However the CTR was considered to be affected either way by the teacher's skill but the result was consistent with the expected effect of sound absorption. Though a weak verification, we examined the teacher on the video and could not find much difference of communication skill which might cause a difference in Group C. Also the teacher of Group D was the same throughout the experiment. As a whole, though with several limitations, it is considered that an evidence of the effect of sound absorption on the children's concentration was obtained.

4. CONCLUSIONS

In this study, concentration of children aged 1 and 3-5 years old to teacher's speech in the acoustic conditions of temporal installation of sound absorption was examined through behavioral observation. Though there were several limitations of experiment due to the limited control over the situation in the actually running daycare centers, the result indicated an increase of concentration with sound absorption and this can be regarded as an evidence of the benefit of good speech intelligibility by means of acoustic design. On the other hand, this is the first attempt and contains lot of points to improve for further studies, such as detailed activity planning with teachers, variation of activity, high resolution camera and so on. Though field experiments in actual daycare center has various limitations, accumulation of studies, even with limitations, should be needed to clarify the effect of acoustics on children.

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