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SPATIAL SETTING WITH SOUND-ABSORBING MATERIALS FOR USE IN AFTER-SCHOOL DAY SERVICE FACILITY FOR CHILDREN WITH DEVELOPMENTAL DISABILITIES

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ABSTRACT

Children with developmental disabilities such as autistic spectrum disorder have a high possibility of showing atypical sensorial characteristics. Schools and after-school facilities should provide a learning and living environment for these children. However, the current environment is unsuitable because it is too noisy for children with hypersensitivity. In this study, we developed a spatial setting that considers the atypical auditory characteristics of children with developmental disabilities to improve their comfort by adjusting the sound environment in an after-school day service facility. First, we measured the sound environment, observed activities of children, and conducted interviews of the support staff of the facility. Based on the problem and requirements indicated by the survey, we installed a spatial setting. It consisted of small boxes with sound-absorbing materials attached inside to allow a child to place his/her head or whole body and take rest in a quiet environment. It also included a foldable partition, tent, and curtain made of sound-absorbing fabrics. This spatial setting functions as a place for children to escape from environmental stimuli, calm down, and change their feelings. According to the support staff, this setting is also effective for processing auditory information, improving concentration, and facilitating communication.

Keywords: *nursery room, sound environment, developmental disabilities, calm-down space, universal design*

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1. INTRODUCTION

In recent years, there has been growing social interest in the need for reasonable accommodations for the sensory characteristics of people with developmental disabilities. People with developmental disabilities, especially those with autistic spectrum disorders, often exhibit atypical sensory characteristics [1, 2]. A high percentage of them tend to have hypersensitivity, which may interfere with their daily lives.

Regarding the learning and living environments of children with developmental disabilities, it has been pointed out that in addition to school education, there is a need to develop places for after-school activities. In Japan, after-school day service centers that provide developmental support according to individual situations have been established. The guidelines [3] state that it is necessary to secure "a quiet space where children can rest when they feel unwell;" however, they do not provide specific methods for setting up such spaces.

A previous study [4] reported that few facilities have environmental settings that are appropriate for children's disabilities and activities. An observational study conducted in a one-room facility confirmed the need for space to ensure children's calmness when static and dynamic activities were mixed. In addition, the use of furniture to separate zones for static and dynamic activities has been shown to be effective in improving the quality of support and activities. Based on these findings, this study proposes a spatial setting that focuses on the sound environment, considering the sensory characteristics of children with developmental disabilities. At an afterschool daycare service facility, we conducted a field survey to understand the problems related to the sound environment during activities, introduced a spatial setting with equipment using sound-absorbing materials, and verified the effectiveness of the setting.

2. FIELD SURVEY OF THE FACILITY

2.1 Method

Field surveys were conducted using acoustic measurements, observation, and interviews at a one-room after-school day service facility in Tokyo. Approximately 10 children and students between the ages of 3 and 18 use the facility each day, and activities such as sensory integration play, artwork, and music therapy are offered. As shown in Figure 1, the facility is divided into two areas: Area A is equipped with bolsters and hammocks suspended from the ceiling for sensory integration play, while Area B has a table and desks and chairs for deskwork and a sofa for reading and calming down.

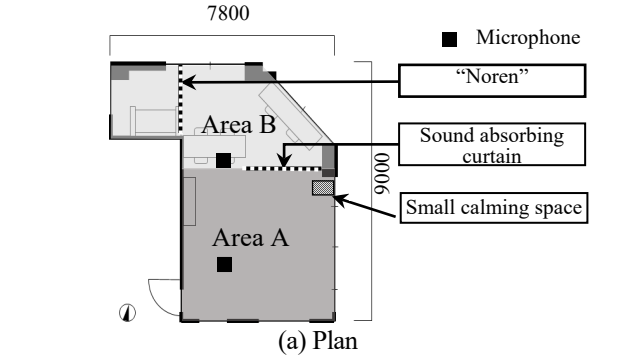
Measurements were taken to assess the sound environment during the activities. Microphones of the sound level meter (RION, NL-42) were installed at two locations in the room (see Fig. 1(a)), approximately 30 cm below the ceiling, and connected to a recorder (Olympus, DS-901) via an extension cable to record the sound environment during the activity (13:30–18:30) for four days. The equivalent A-weighted sound pressure level ($L_{Aeq,\ 1min}$) was analyzed every minute from the recorded sound. In addition, an observational survey was conducted to record the activities of children and students, and activities in each area were categorized as static or dynamic activities.

For the room acoustic characteristics, reverberation time was measured under unoccupied condition. Measurement was taken six times using a precision-class sound-level meter (RION, NA-28) and a reverberation-time analyzing system (RION, NX-28BA) with a paper made impulse sound source.

In addition, the support staff were interviewed regarding problems and requirements related to the sound environment.

2.2 Results

Figure 2 shows the equivalent A-weighted sound pressure level ($L_{Aeq,\ 1min}$) measured on a typical day and the results of the observational survey, which were classified into static and dynamic activities for each area. Although differences between days due to activity content were observed, the A-weighted sound pressure level ($L_{Aeq,\ 1min}$) during the activities in the facility commonly ranged from 50 dB to 80 dB. In the observational survey, dynamic activities such as sensory integration play were more frequently observed in Area A, while static activities such as artwork and reading were observed in Area B. Around 16:00, when the A-weighted sound pressure level ($L_{Aeq,\ 1min}$) was particularly high, three children were seen lying down, looking tired, in



(a) Plan

(b) Activity in Area A (c) Activity in Area B

Figure 1. The afterschool daycare facility

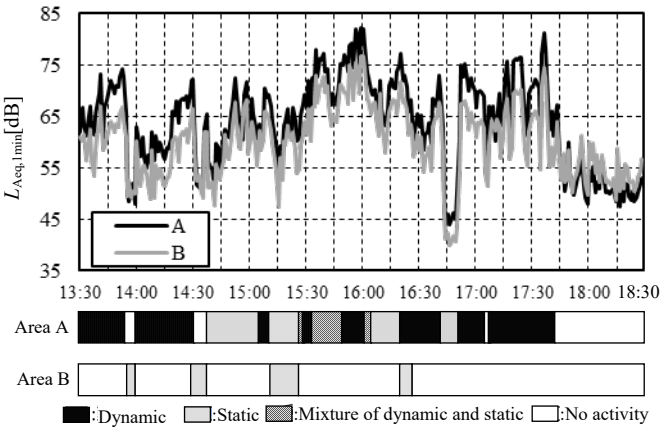


Figure 2. $L_{Aeq,1min}$ on a typical day and the classification of activities

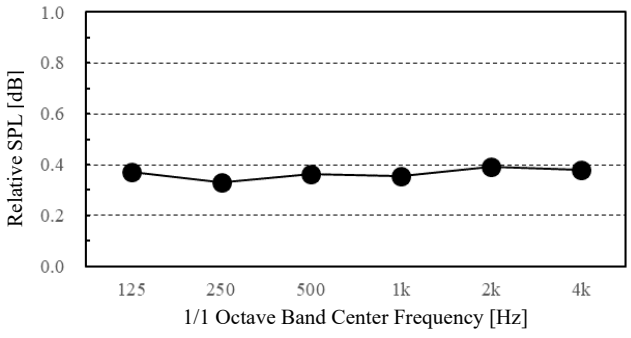


Figure 3. Reverberation time

an area close to the place where five or six children were engaged in sensory integration play and music therapy.
In Area B, where static activities took place, the sound environment was influenced by the activities taking place in Area A. Accordingly, there was little difference in the A-weighted sound pressure level ($L_{Aeq,\ 1min}$) between the two areas. This confirms that the sounds emitted from the static and dynamic activities were mixed and generated a unified sound environment in the room.
Figure 3 shows the measurement result of the reverberation time. No sound-absorbing materials were used in the architectural finishes of the ceiling and walls, however, the reverberation time was short, less than 0.4 seconds. This could be attributed to the fact that the floor was covered with a soft urethane mat and that many objects were placed in the room. Therefore, it is considered that the problem with the sound environment is not due to reverberation in the room, but to the mixing of sounds.
From the interview of the support staff, the following points were raised: "Sound reflection and noise may create a situation where children are prone to emotional instability," "It would be good to have options such as partitions or small rooms to reduce sound stimulation," "I feel the need for a calming down space, but it is difficult to install due to the spatial limitations." These comments suggest the need for a space in which children can escape sound stimuli.

3. INTRODUCTION OF SPATIAL SETTINGS

Based on the survey results, spatial settings using six types of equipment with sound-absorbing materials were proposed and installed (Fig. 4), and their effectiveness was verified through interviews.
To understand the acoustic characteristics of each piece of equipment, we measured the attenuation performance of external sound. Pink noise was emitted from a sound source (YAMAHA MSR5 STUDIO), and the microphone of the sound level meter (NA-28, RION) was placed at a sound-receiving point 1.4 m away from the source. From the measurement results, the relative sound pressure levels in each 1/1 octave band were analyzed under the no-equipment condition.
After installation, the usage and efficacy of each piece of equipment were investigated through interviews (Tab. 1).

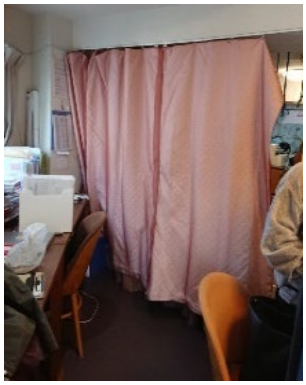
3.1 Small calming space

A "small calming space" was made as a compact calming space for one person to escape from sound stimuli by entering the space (Fig. 4(a)). The concept was the same as that of our previous study [5], but we intended to increase


(a) Small calming space



(b) Calming box


(c) Sound absorbing curtain

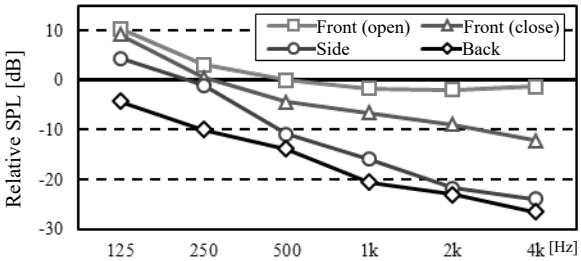

(d) "Noren"


(e) Sound absorbing tent

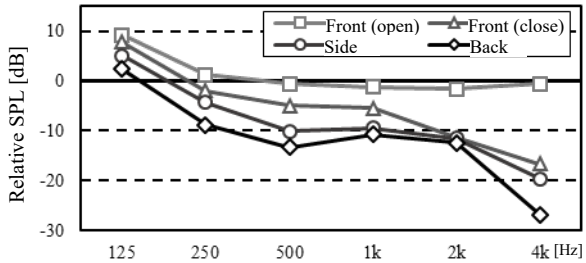

(f) Foldable partition

Figure 4. Equipment with sound absorbing material

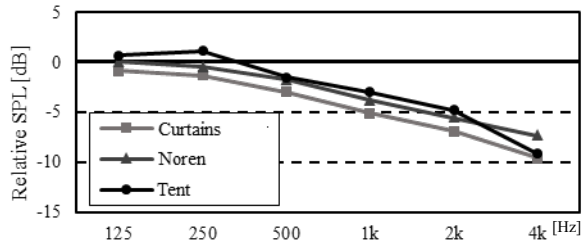
the sound insulation performance. The space was made of plywood (15 mm) with an opening on one side. A cushion-like sound-absorbing material (POLYWOOL®, 30 mm, Fukoku Co., Ltd.) wrapped in non-woven fabric was placed on the inside sides and top, and a cloth-like porous sound-absorbing material (TAFNEL ®, Mitsui Chemicals Inc.)



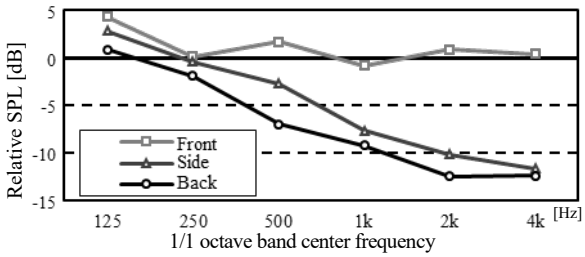
(a) Small calming space



(b) Calming box



(c) Equipment made of cloth-like sound absorption materials

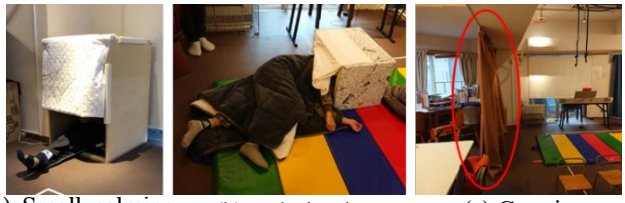


(d) Foldable partition

Figure 5. Attenuation performance

was hung from the top of the opening. A mat was then placed underneath. The size of the space was set such that the entire body of a child sitting on the floor holding his/her knees would fit (W60 × D63 × H83 cm^3).

The sound attenuation performance was measured under four conditions: front (with and without the cloth-like sound-absorbing material), side, and back. Figure 5(a) shows the relative levels of sound pressure. Attenuation was greater at higher frequencies and sounds from the sides and back were attenuated by approximately 15 and 20 dB in the 1 kHz octave band.



(a) Small calming space (b) Calming box (c) Curtain

(d) "Noren" (e) Tent (f) Foldable partition

Figure 6. Equipment in use

When the space was installed, approximately ten children habitually used it (Fig. 6(a)). They used it when they felt it was necessary, such as when they wanted to calm their anxiety or excitement at the end of an activity. In addition, a support staff commented, "It is easy to listen to speech when the person is in the space because the direction of the sound comes from one direction, from the front," suggesting that the equipment aids in auditory information processing. However, it was also pointed out that "It is difficult for children who are uncomfortable in a closed or dark space to use the small calming space."

3.2 Calming box

The calming box was proposed as a lightweight, portable small calming space. A cardboard box with an opening on one side was used for the exterior, the cushion-like sound-absorbing material wrapped in non-woven fabric was attached to the inner side and top, a cloth-like sound-absorbing material was attached to the top of the opening, and a transparent plate was attached to the back so that the outside could be seen (Fig. 4(b)). The equipment was designed to accommodate the head and placed on a desk (W53 × D38 × H38 cm^3).

The sound attenuation performance results are presented in Fig. 5(b). The attenuation of sound was greater in the higher frequency range, and the sound from the sides and back was attenuated by approximately 10 dB in the 1 kHz octave band.

Initially, the equipment was intended for use with the head placed in a sitting position. However, it was mainly used with the head placed in a lying position on the floor (Fig. 6(b)). It was suggested that the product would be effective for children who have tactile sensitivity in addition to sound

sensitivity, since we obtained opinions such as "Compared to earphones and earmuffs with noise cancellation functions, the product is good because it is less likely to cause tactile sensitivity." One adult who took the equipment home and used it at bedtime commented, "Using the calming box, I can sleep better now as the sound and light are reduced, and the quality of my sleep has improved."

3.3 Sound absorbing curtains

Curtains made of cloth-like sound-absorbing material were installed to gently divide the sound environment between Areas A and B (Fig. 1). The sound-absorbing material was covered with a thin cloth and several holes were drilled on one side of the material, which was then attached to the existing curtain rail using a ring (Fig. 4(c)). The size of the curtains was 190 × 330 cm^2 to match the existing curtains. Measurements were taken under two conditions, with and without the sound-absorbing curtain, and an attenuation effect of approximately 5 dB was confirmed in the 1 kHz octave band (Fig. 5(c)).

The product was mainly used during music therapy and in the presence of office staff (Fig. 6(c)). Sound-absorbing materials cut small sounds generated by office work and are particularly effective for children who are sensitive to the presence of others. In addition, it was noted to be effective in enhancing concentration; we received comments such as "By reducing the sound that enters the ears, the children's attention is less interrupted, and their concentration is increased."

Table 1. Equipment usage and efficiency reported by support staff

Small calming space	• About 10 children enter the small calming space and use it for about 5~7 minutes. • Children enter the small calming space by themselves when they feel the need. • Children enter the small space not because of noise, but because they need to settle anxiety and heightened feelings when an activity is ending. • There were children who stayed in the space and participated in the activity. • It is good that the direction of the sound is unidirectional from the front.
Calming box	• Used in the form of lying down when calming down. • It is quieter and calms a child down. • It is easier to use it lying down because it is hard to use it sitting down. • When I use it every day at bedtime, the quality of my sleep improved. I noticed changes in my physical condition as I was able to sleep better. • It is better than earphones or earmuffs, which are more likely to cause tactile sensitivities.
Sound absorbing curtain	• Sound-absorbing curtains are closed when music therapy is performed or when office staff is present. • Rather than loud noises, noises such as subtle work noises (turning papers) are reduced. • The child is less likely to be distracted. • The effect was seen in children who are sensitive to the presence of office workers.
"Noren": Sound absorbing narrow width curtain	• The room (around the sofa) has a subtle private room feeling, and the visibility is blocked. • The room was not as quiet as the small calming space, but it was quiet enough for a calm and relaxing stay. • When used in combination with the curtains, it was possible to provide a gradual sound insulation, and the environment was set up gently.
Sound-absorbing tent	• Two children were chatting in the sound-absorbing tent, and it became a good space for communication. • The sound and conversation around them became muffled when they entered the tent. • As there is no feeling of being cramped, it is comfortable to use for people who are not comfortable in dark or small spaces.
Fordable partition	• Used for making artwork, studying, and reading. Improved concentration on the work. • When reading a picture book, the bath towel was placed on top of the partition, enabling the children to listen quietly even when there were many people around. • Good for children who want to participate in activities but feel uneasy without their safety zone

3.4 "Noren": Sound-absorbing narrow width curtain

Similar to the sound-absorbing curtain, a sound-absorbing narrow width curtain which we called "Noren" was installed. The cloth-like sound-absorbing material was covered with a thin cloth, attached using a tension rod, and hung from the ceiling (Fig. 4(d)). The size was 235 × 110 cm^2 in accordance with the installation location, to minimize the gap around each side as much as possible.
The sound attenuation performance was approximately 4 dB at the 1 kHz octave band, with higher attenuation at higher frequencies (Fig. 5(c)).
The installation of "Noren" created a space in which sight and sound were gently sheltered, producing a "soft private room feeling" around the sofa (Fig.6(d)). It was used as a calming space for a tired child who wanted to keep a distance from the sounds. In addition, comments such as "When used in combination with curtains, the space in the room can be gradually distanced from sound," indicated that it is effective in setting up gentle environmental divisions. However, there was also a comment that the curtains blocked visibility and air conditioning.

3.5 Sound-absorbing tent

The tent was set up as a calm-down space that could be used without the locked-up feeling of the small calming space and could be easily stored and moved (Fig. 4(e)). A cloth-like sound-absorbing material covered with a thin cloth was sewn onto a circular frame and hung using ropes. The space was large enough to accommodate two children sitting on the floor.
The sound attenuation performance (Fig. 5(c)) showed that the attenuation was greater in the higher frequency range, and an attenuation effect of approximately 3 dB was observed in the 1 kHz octave band.
This equipment was used for reading and conversation among children (Fig. 6(e)). It was commented that was that the space made it easy for those children who had difficulty in forming conversations due to sounds around them to communicate with each other. In addition, because there was no feeling of being cramped, the device was effective for children who had difficulty using small spaces because they were uncomfortable in closed, dark, or confined spaces. In addition, movability was evaluated highly, with comments such as "I like that it is easy to carry and install."

3.6 Foldable partition

A cloth-like sound-absorbing material was attached to a ready-made foldable partition in order to create a space where people could concentrate by cutting not only the surrounding view but also the sound (Fig. 4(f)). A cloth-covered sound-absorbing material was attached to the inner sides of the foldable partition using Velcro tape. The partition was sufficiently large (W65 × D60 × H130 cm^3) to completely enclose the entire body while sitting on a chair.
As shown in Fig. 5(d), the attenuation performance was greater at higher frequencies, and the sound from the sides and back was attenuated by approximately 8 and 9 dB in the 1 kHz octave band.
While foldable partitions were often installed in front of a child to block visual information on the front and sides, in this case, they were installed and used to block the back and sides (Fig. 6(f)). They were used for making artworks, studying, and staff reading to the children, and comments such as "children can concentrate more on their work" were obtained. Here, it was suggested that environmental sound was not only reduced overall but also that the directionality of sound was limited to the front, which aided auditory information processing.

Table 2. Comments on the findings from usage experience

- Until now, the only way to support children with sound sensitivity was to block their hearing by wearing noise-canceling earphones or earmuffs, but some children had difficulty with these due to tactile sensitivity, so I thought it would be good to reduce sound stimulation from an environmental perspective in a gentle way.
- A child used the sound-absorbing foldable partition lying down in combination with the relaxation box and commented, "It is good not to hear voices outside, I can sleep well here." The children were creating a space where they could relax by themselves by combining the assistive equipment.
- The aids were necessary because they could be used for various purposes such as study, change of feelings, relaxation.
- Trying out different types of aids led to "self-knowledge" of what they need.
- Actual experience will lead to the understanding of conditions that are comfortable for children. It is important for adults to feel it first.
- The aids are not just for one person, so it is not an individual problem, but helps to understand problems of other people.
- It is helpful to be able to store and move the assistive devices in a limited space.

3.7 Overall review

We asked the support staff about their findings regarding the installation and trial use of the six types of assistive equipment. As shown in Tab. 2, the spatial setting built using assistive equipment was confirmed to be highly useful in facilities with limited space.

4. SUMMARY

In this study, six types of equipment using sound-absorbing materials were proposed and their effectiveness was verified at an after-school day service facility. The results of the study showed that equipment with sound-absorbing materials served as a place to escape environmental stimuli, calm down, and change feelings. In addition, the equipment was effective in aiding auditory information processing, enhancing concentration, and facilitating communication. Consequently, it was confirmed that these were effective as environmental setting methods that considered the sensory characteristics of people with developmental disabilities and that they could improve the quality of support in activities.
Our previous study that have enhanced sound absorption in a whole nursery room in the child development support center suggested that the sound environment could improved by sound absorption, and this effect supported calmness, ease of participation in activities, and language development among children [6]. The equipment using sound-absorbing materials suggested in this study have a certain effect even when it is difficult to improve the acoustic performance in an entire room, and are expected to be widely used as an environmental adjustment method that is easier to introduce.

5. ACKNOWLEDGMENTS

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