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Designing a Conversation Support Tool for Quiet Environments by Focusing on the Characteristics of Ultrasonic Waves

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Abstract

In a quiet environment, even a small noise attracts the attention of the people around. In order to reduce the stress of speakers, listeners, and other people around them, we devised a tool to support conversation by converting voice into ultrasonic waves and outputting them from parametric speakers to deliver the sound to the conversation partner. Since light materials can be used for soundproofing ultrasonic waves, we used cardboard and newspaper as soundproofing materials. We confirmed that the sound converted by the tool can be used for conversation and soundproofed.

Keywords: ultrasonic wave, conversation support, communication, problem solving, product design

1. Introduction

In a quiet environment, noise problems are likely to occur, and the satisfactory solutions cannot be always found. This is because the surroundings are so quiet that even a small sound becomes a noise. In particular, sounds related to the human voice are likely to be the cause of noise.

An example is the noise problem in a shared hospital room. The noise in hospital rooms is generated by medical equipment and the work of doctors and nurses. In particular, the noise generated by patients is often unpleasant for them. According to a questionnaire survey conducted by Mori, et al. (1986), 75% of the sounds that hospitalized patients perceive as noise during the day are generated by the patients. The top 54% of these noises include snoring by roommates, children's crying, talking in the lobby, doors opening and closing, and the voices of visitors. In a shared room, multiple patients live together in a hospital, so problems are more likely to occur than in a private room. However, due to the shortage of hospital rooms and cost issues, not all patients who wish to have a private room are able to do so. It is desirable to solve the noise problem in hospital rooms for the purpose of treatment and physical recovery.

There is also a serious noise problem in shelters set up in response to sudden natural disasters such as typhoons and heavy rain. It has been pointed out that the living environment in shelters in Japan is below the Sphere standard. According to a survey by Nagahata (2017) noise problems in particular have a high correlation with stress and discomfort. Among them, the human voice is one of the top causes. In Japan, where disasters occur frequently, improving the living environment related to sound in shelters is an important issue.

In this study, we investigated noise reduction for quiet environments where large-scale noise reduction cannot be implemented. Various methods are currently used for general noise control. One of the main methods is soundproofing. It is a method of enclosing the source of sound with a soundproofing wall to prevent the sound from leaking out of the enclosed space to the outside or being conveyed from the outside to the inside of the space. There are two main types of soundproofing: passive noise control (PNC) and active noise control (ANC).

PNC is a soundproofing method that utilizes the physical properties of materials such as sound insulation and sound absorption materials. It is used in various situations, such as walls, sound insulation sheets, and earplugs. These soundproofing methods can be divided into two categories: sound insulation and sound absorption. Sound insulation means that sound waves propagating in the air are blocked by a shielding material, preventing the transmission of sound energy to the opposite side. The difference in sound pressure level between incident sound and transmitted sound is also called transmission loss (TL), and is expressed as the difference between incident energy and transmitted energy. The higher the transmission loss, the higher the sound insulation effect of the shielding. The transmission loss increases with the surface density of the shielding and the frequency of the incident sound. This is called the mass law, and when the surface density of the shielding is m (kg/m^2) and the frequency is f (Hz), the transmission loss TL_0 for perpendicular incidence can be expressed by the Equation 1 (Uchikawa, 2008).

$$TL_0 = 20\log_{10}(f \cdot m) - 42.5 \tag{1}$$

Therefore, materials with high areal density are generally used. On the other hand, sound absorption is to attenuate the sound energy by converting the incident sound into thermal energy inside the material. Sound-absorbing materials generally have a fibre or porous structure, and convert the incident sound into thermal energy by taking it inside and vibrating it.

ANC is a method of cancelling out noise by generating sound waves that are in phase opposite with the wavelength of the noise. ANC is easily applied to plane wave propagation such as ducts and small closed sound fields such as earphone. On the other hand, it is difficult to apply the method to a sound field where spherical waves propagate, such as in a room. This is because the target noise and the control sound interfere in the same phase depending on the location, and the sound is amplified.

In this study, we focus on conversational noise in a specific quiet environment such as a shelter or a shared room in a hospital. In this environment, there are speakers and listeners in the conversation space, and other people who perceive the conversation as noise outside the space. In such a quiet environment, even a whispering voice becomes a noise. The people feel stressed when they hear irrelevant voices while sleeping or resting. It is also stressful for the conversation partners to talk while paying attention to the sound leakage to the surroundings. In general, an effective solution to this problem is to provide a space with no sound leakage, such as a soundproof room. However, it is often difficult to provide such facilities in shelters or in shared hospital rooms. In addition, earplugs or noise-cancelling earphones can be used on an individual basis, but this can cause problems such as miss hearing emergency announcements. Therefore, we propose a unique noise reduction method that reduces the stress of all the speaker, listener and other people around them.

2. Approach

2.1. Idea

Figure 1 shows an image of the environment assumed in this research. First of all, it is necessary to convey the voice only to the conversation partner with consideration for sound leakage to the surroundings. In a usual conversation, other people around the conversation partner can hear the voice due to the diffraction and spread of the sound. Therefore, it is desirable to convey the voice directly to only the conversation partner with pinpoint accuracy. In addition, it is necessary to confirm that the conversation partner can recognize the voice. For this reason, gestures such as nodding in response to the speaker's voice should always be visible.

In order to create a system in which a voice can be directly conveyed to the ear of the conversation partner, we focus on the characteristics of sound waves. The shorter the wavelength of a sound wave, the higher its directness. Therefore, we focused on ultrasonic waves. Since the ultrasonic waves indicate a shorter wavelength than audible sound, it is less diffuse and more directional. By using ultrasonic waves, we investigated a method to convey the speaker's voice to the listener only. In addition, it was necessary to be able to read the facial expression without hiding the face as much as possible.

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On the other hand, since ultrasonic waves have excellent linearity, ultrasonic waves can convey to other people beyond the conversation partner. Therefore, it is necessary to take into account the characteristics of them in soundproofing. In an environment such as a shelter or a hospital room, it is required that the soundproofing measures be easy to install, remove, assemble, and use. For example, during disasters the soundproofing material should be easily accessible. On the other hand, in hospitals, it should be easy to install and remove. In light of the above, an approach is required to deal with the noise problem, which is to prevent or reduce the sound leakage of conversation causing the noise. In this study, we investigated the method to reduce the sound leakage.
In general soundproofing, it is effective to enclose the sound source with heavy soundproof walls to prevent sound from leaking out. However, since ultrasonic waves will be used in this project, it is necessary to implement soundproofing measures based on the characteristics of them.

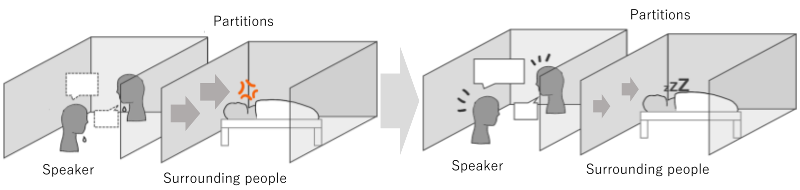

Figure 1. Noise problem in a quiet environment

2.2. Properties of ultrasound

Ultrasonic waves have a frequency of 20 kHz or higher and are generally not audible to humans. They propagate in media such as gases, solids, and liquids, and do not propagate in a vacuum. They are also partially reflected at boundary surfaces where the properties of the medium differ. The acoustic pressure reflectance R of ultrasonic waves is expressed in Equation 2 using the acoustic characteristic impedance Z_i of each medium and Z_i is expressed in Equation 3 using the density of the medium ρ and the sound velocity C in the medium (Yokono, 1995).

$$R = \frac{Z_2 - Z_1}{Z_2 + Z_1} \tag{2}$$

$$Z_i = \rho C \tag{3}$$

Equation 2 shows that the sound pressure reflection coefficient increases with the difference in the acoustic characteristic impedance of the media. Since the acoustic characteristic impedance of air is much smaller than that of solids, ultrasonic waves conveying through air tend to be reflected when they hit an object. Therefore, they can have a higher reflectivity than audible sound even in lightweight materials with low density and low acoustic characteristic impedance.

2.3. Parametric speaker

In this study, we focused on parametric speakers, which can convey audible sound while utilizing the characteristics of ultrasonic waves with high directivity. The parametric speakers can convey sound in a straight line to the target, while ordinary speakers convey sound to a certain area around them by diffraction. Parametric speakers modulate the signal from the sound source into an ultrasonic wave called a carrier. This ultrasonic wave is distorted by the nonlinearity of the air, and is then self-demodulated, allowing the human to perceive the same sound as the source. Frequency modulation and amplitude modulation are the main modulation methods used. Figure 2 shows an explanation drawing of each modulation method (Ship's Electric Installation Contractor's Association of Japan, 2005). Figure 2 (a) shows the signal of a sound source. As shown in Figure 2 (b), frequency modulation expresses the signal of a sound source by changing the frequency of the ultrasonic wave according to the amplitude and wavelength of the source signal. Since the amplitude after modulation is constant, it is resistant to noise. On the other hand, as Figure 2 (c) shows, amplitude modulation is a method of changing the amplitude of the ultrasonic wave according to the amplitude and wavelength of it. The envelope of its amplitude represents the sound source. Since the frequency band used is narrow, this method is suitable for cases where the frequency band is limited. Parametric speakers

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improve directivity by adding ultrasonic wave's characteristics to the reproduced sound, but their use is limited by problems such as insufficient sound pressure and degradation of sound quality.

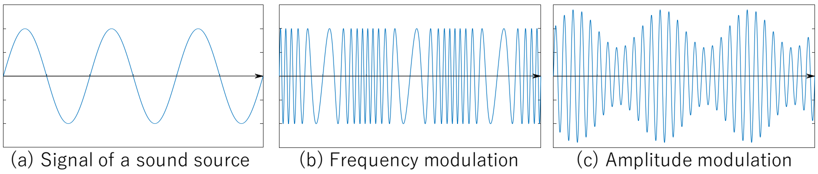

Figure 2. Image of the modulation method

2.4. Sound insulation and absorption of ultrasonic waves

The sound output from a parametric speaker reflects well when it hits an object. This is due to the nature of ultrasonic waves. Therefore, unlike audible sound, it is possible to reflect and block sound even with lightweight materials. So we decided to use cardboard, which is often used for partitions in shelters, as a sound insulation material. However, when sound insulation measures against ultrasonic waves are taken, the reflected sound is not attenuated and is reflected again and again in the enclosed space. Therefore, it is also necessary to implement sound absorption measures to attenuate the reflected sound. The attenuation of sound by sound-absorbing materials occurs when they vibrate and the sound energy is converted into thermal energy. Accordingly, based on this environmental setting, we studied the manufacturing and use of sound-absorbing materials that are available in a limited environment. We decided to use newspaper as a material that is relatively easy to obtain and process.

3. Development of tools

3.1. Design

In this study, we have developed a unique conversation support tool using parametric speakers that conveys human voice for conversations. Figure 3 shows an image of the usage environment. The speaker's voice is input to the parametric speaker by a microphone sensor and output as ultrasonic waves. They are highly directional, so that the sound output through the tool travels to the conversation partner's ear in a straight line, thus preventing the sound of the conversation from spreading to the surrounding area. In addition, due to the nature of ultrasonic waves, even lightweight partitions such as cardboard can be used for sound insulation, making it easy to implement noise reduction in a place such as shelter. Focusing on these properties of them, we designed the tool with the following three functions. The first is to reduce the sound leakage of the human voice during voice input. Therefore, we decided to cover the microphone sensor to prevent the input sound from leaking out. Since the environment was assumed to be quiet, it was expected that the conversation would be quieter than usual. So the voice input to the tool becomes quiet, and even a lightweight cover can provide sufficient sound insulation. The second is that conversation partner is able to recognize the content of the sound output from the tool. If this function is not achieved, the conversation cannot be established and the tool cannot fulfil its important role as a conversation support tool. Therefore, we used commercially available parametric speakers with frequency modulation for the modulation circuit, which affects the sound quality. The third is that the tool does not affect the user's posture during conversation. Since the tool is touched around the mouth, it must be held by hand at all times during conversation. This also affects eye contact, which is important in conversation. Therefore, the shape of the tool must be such that it can be held with one hand and used while looking at conversation partner.

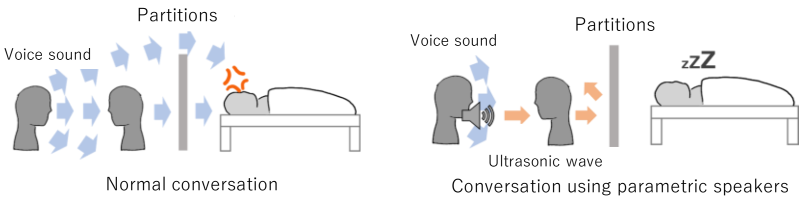

Figure 3. Idea of reducing the leaked voice sound by focusing on ultrasonic waves

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3.2. Implementation

The tool can be divided into three main parts: the voice input part, the main body case, and the modulation circuit and audio output part. Figure 4 shows the tool and its internal circuit.

The voice input part consists of a microphone sensor and a microphone cover. The microphone sensor is fixed by inserting it into the hole of the cover. The microphone cover has a curved surface to be used in close contact with the mouth. A parabola-shaped microphone cover was fabricated using a 3D printer, focusing on the shape of microphone covers used for karaoke and singing practice at home. In order to reduce discomfort during use, or sticking and holding, the entire surface, not just the part that contacts the mouth, was made into a curved surface. The 3D printer was used for two reasons: first, the input voice to the tool is expected to be quiet, so even a lightweight 3D printer resin can be used for sound insulation. The other reason is that it is easy to mould a curved surface shape. The main body case serves to hold each part. The dimensions of the case were set to 125 $\times$ 73 mm at the bottom, referring to a smart phone, in order to allow operation with one hand. As shown in Figure 4 (a) and (b), the ultrasonic generators are inserted into the front hole and the microphone cover is inserted into the top hole. The microphone cover was installed at a 45° angle to the oscillating surface of the ultrasonic generators to make it easier to talk face to face with the partner. When the user puts the microphone cover over the mouth and looks at the face of the conversational partner, voice is output from the speaker to the partner. In addition, the microphone cover is designed to be inserted into the hole of the main body case and not fixed, so that the user can easily adjust the angle to head for the partner. The bottom of the case has a space to store a mobile battery to power the modulation circuit. In consideration of the ease of maintenance of each part, the microphone cover, ultrasonic generators, and mobile battery are fixed by simply inserting them into the holes provided for easy removal. For the modulation circuit and audio output section, the circuit was divided into two stages to make the tool smaller. In the lower stage, the circuit is placed that the audio input signal is converted into ultrasonic waves and amplified. A parametric speaker kit (Tri-State) was used for the circuit. In the upper part, the power supply for the microphone sensor and the wiring for the signal input from the microphone sensor to the parametric speaker are placed. Since the parametric speaker requires a 9V power supply, we used a mobile battery and a voltage booster from 5V to 9V. This makes it possible to use the tool even if there is no power supply around. On the audio output side, twenty ultrasonic generators are arranged in four rows and five columns.

(a) Tool side and front (b) Main body case (c) Internal circuit

Figure 4. A conversation support tool and assembly

Figure 5 shows how to use it. At the time of design, we had assumed the use as shown in the left figure, but by not fixing the microphone cover, we found the use as shown in the right figure. The main unit can be placed on a desk, so it can be used with one hand. It is also possible to use the device while wearing a mask.

Figure 5. Scenes in using the tool

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3.3. Sound-absorbing materials

For the sound-absorbing material, we decided to use a familiar material, newspaper. Cellulose fibre, which is made from newspaper, is widely used as a heat insulator for houses in the U.S., and has recently begun to be used in Japan as well. The fibres of various thicknesses are intertwined to create many fine air chambers, resulting in high sound absorption performance. In this study, referring to the manufacturing process of cellulose fibre, we decided to manufacture a material with similar properties to cellulose fibre with familiar equipment and use it as a sound-absorbing material. First, newspapers are crushed to the size of postage stamps and stirred with boric acid and borax. The mixture of boric acid and borax enhances the flame retardant effect, and also serves as a measure against insects and mould. The material is then crushed and stirred until it becomes fibrous. This allows the chemicals to stir evenly and the fibres to contain air for insulation. In order to follow this process in a simple way, we focused on the method of making paper at home. In this method, used paper is crushed in a household mixer to loosen it into fibres. When the fibres could be dried in a loosened state, it was thought that a material similar to cellulose fibre could be produced. Therefore, a sound-absorbing material made from newspaper was fabricated using the following method. Boric acid does not affect the sound absorption effect, so it is not used in this study. First, newspapers were shredded into 25 mm squares, and the newspapers and water were stirred in a mixer. Then, it was put out on a net, water was squeezed out, and it was spread out to dry for a day or two. After the water has evaporated, the material is crushed again in a mixer to make it cotton-like. Figure 6 shows the sound absorption material produced by this method. The sound-absorbing material was packed in a net and installed as a cushion.

Figure 6. Sound-absorbing material placed inside the box

4. Experiment

4.1. Purpose of the experiment

In this study, we have developed a tool for conversation that uses ultrasonic waves. In the experiment, we investigate whether it is possible to use the tool and whether the output sound of the tool can be muffled by a simple soundproof wall. In this experiment, we assumed that the tool would be used inside a cardboard partition. In Experiment 1, the sound pressure level was measured by a noise meter in order to investigate the effect of the sound absorption material and the sound leakage reduction effect of the partition when using the tool. In Experiment 2, we conducted a survey on voice recognition. Specifically, we conducted a listening survey and a questionnaire survey in order to compare sound presented directly from tools and speakers with sound leaked by various sound insulation and absorption methods. This research has been conducted after approved by Ethics Review Committee on Research with Human Subjects. The subjects were explained the contents of the experiment and consented in advance. The subjects were four males in their 20s and two females in their 20s who had no auditory dysfunction.

4.2. Experiment 1: Performance test

We investigated the effect of sound leakage reduction in partitions when using the tool and the effect of sound-absorbing material using newspaper. The experimental procedure is described below. In order to compare the results of the tool, a commercially available portable speaker was used. First, the tool or portable speakers were placed on the top of table. Then, white noise was played from each device. The sound pressure level was set to 40, 45, 50, 55, 60 dB at a distance of 1 m using a noise meter. After that, the sound pressure level was measured for 10 seconds under the following conditions (1) to (4): (1)

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not covered, (2) covered with a cardboard box, (3) covered with a cardboard box filled with sound-absorbing material made from newspaper, and (4) covered with a cardboard box filled with corrugated board. A cardboard box W515, D415, H450 was used for each condition. The volumes of the hollow space in (3) and (4) are equal. The scenes of experiment 1 are shown in Figure 7, and the measurement results are shown in Figure 8. The results are the equivalent noise levels calculated by the function of the noise meter. The equivalent noise level is a measure of the average noise level during the measurement time. The background noise level in the room was 24.7 dB.

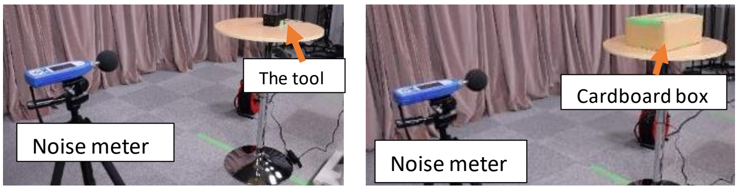

Figure 7. Measurement scenes of Experiment 1

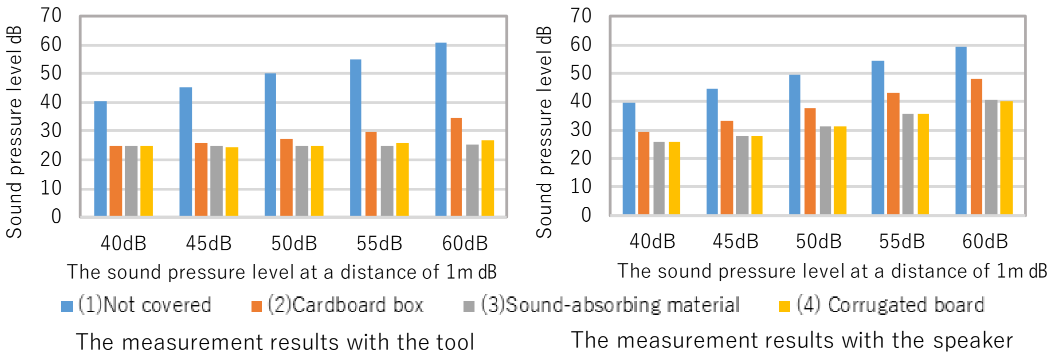

Figure 8. The measurement results of Experiment 1

For both devices, the sound pressure level was reduced by the soundproofing measures. Comparing conditions (3) and (4), the sound pressure level did not change much. When the tool was used as the sound source, the sound pressure level was always less than 30 dB in conditions (3) and (4) regardless of the output sound pressure. The background noise is 24.7 dB, so the soundproofing measures in conditions (2) to (4) are effective enough. In the case of 40-50 dB, there was not much difference between conditions (2) to (4). Comparing conditions (2) and (3), the sound pressure level decreased by 4.7 dB in the case of 55 dB, and by 9 dB in the case of 60 dB. When the speaker was used as the sound source, the sound pressure level decreased by 10 dB or more in conditions (2) to (4) compared to condition (1). Looking at the results above, it can be said that the sound by the tool was easier to reduce than that of the speakers, regardless of the output sound pressure level.

4.3. Experiment 2: Subjective test

We investigated whether it is possible to recognize the sound output from the tool. In addition, the sound leakage reduction effect of the cardboard box was evaluated based on voice recognition. First, the recognition of the reproduced sound by the tool was investigated by means of a listening test of the word reading voice. The subject was assumed to be the conversation partner, and either the tool or the portable speaker was placed in front of the subject's face at a distance of 1m from the ear position of the subject sitting in a chair. As in Experiment 1, a commercially available portable speaker was also used for comparison with the tool. The sound pressure level of each device was set to 40, 45, 50, 55, 60 dB at the subject's ear, referring to the sound pressure level of conversation in Japanese is about 56 dB (Shiraishi and Kanda, 2010). At the set sound pressure level, a male and a female voice file reading 20 words at random were played. The words were chosen from the word list made by Amano and Kondo (2001). The subjects wrote the words they recognized on a survey sheet. In addition, a five-step questionnaire to evaluate subjective sound level was conducted (1: small, 2: somewhat small, 3: just right, 4: somewhat loud, 5: loud. Figure 9 shows the scene of experiment 2. The following are the results of the listening test for words and the five-step questionnaire.

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Figure 9. Scene of Experiment 2

Figure 10 (1) shows that the sound pressure level of both the tool and the speaker in the range of 40 dB to 55dB has little effect on the listening test for words, while the number of correct answers dropped at 60dB in use of the tool because the tool provided noise. Multiple comparisons using the Tukey method were used in Figure 10 (1) and the Friedman test was used in Figure 10 (2). Figure 10 (1) shows that there were significant differences between 40dB to 55dB and 60 dB in use of the tool. Figure 10 (2) shows that the sound pressure level of 45-55 dB is preferable for conversations in both devices.

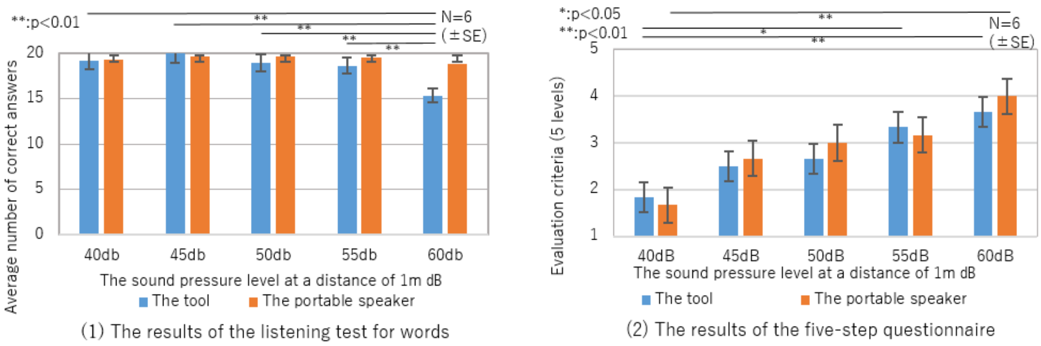

Figure 10. The result of the listening test and the five-step questionnaire

Next, we investigated the effect of soundproofing using cardboard and newspaper on reducing sound leakage and the degree of recognition of voice content assuming conversations in the surroundings. A tool or speaker was placed at a distance of 2.5 m from the subject's ear so that the output surface was in front of the subject's face, assuming that the subject could hear a nearby conversation. The same conditions (1) to (4) as in experiment 1 were used for soundproofing, and a voice file reading 20 words was played. Based on the Visual Analog Scale (VAS), the subjects were asked to mark 100 % when they could hear the sound at a conversational level and 0 % when they could not understand the sound. When the subject could understand the word, he/she was required to write it down on the survey sheet. When the subject could not hear the sound at all, he/she was required to write "X". When the subject could hear the sound but could not recognize the word, he/she was required to write "O". The experiments were conducted in 40, 45, 50, 55, 60 dB conditions. Figure 11 shows the number of correct answers in the word listening survey in each condition, Figure 12 shows the average number of words answered with "X" in the tool listening survey, and Figure 13 shows the results of VAS evaluation in each condition. Multiple comparisons using the Tukey method were used in Figure11, 12, 13.

Figure 11 shows that the number of correct answers decreased significantly with the soundproofing measures when the tool was used. In particular, the number of correct answers of all the subjects sometimes became zero by sound-absorbing material in condition (3) and cardboard board in condition (4). On the other hand, when portable speakers were used, the number of correct answers for conditions (2) to (4) decreased from the number of correct answers for condition (1) at 40-50 dB, and the difference in the number of correct answers for conditions (1) to (4) became smaller at 55-60 dB. Furthermore, Figure 12 shows that there are significant differences between condition (3) and condition (4) under 45 dB to 55 dB when the tool was used. Therefore, conditions (3) and (4) are equally effective in preventing voice recognition, especially condition (3) is more effective in preventing sound leakage. Figure 13 shows that the soundproofing measures made it difficult to hear the sound in both the tool and portable speaker conditions. In the case of the tool, the sound-absorbing material in condition (3) was the most effective soundproofing material at all sound pressure levels. In addition, when comparing the tool and the speaker, it was evaluated that the tool was more effective in soundproofing in all conditions (2) to (4).

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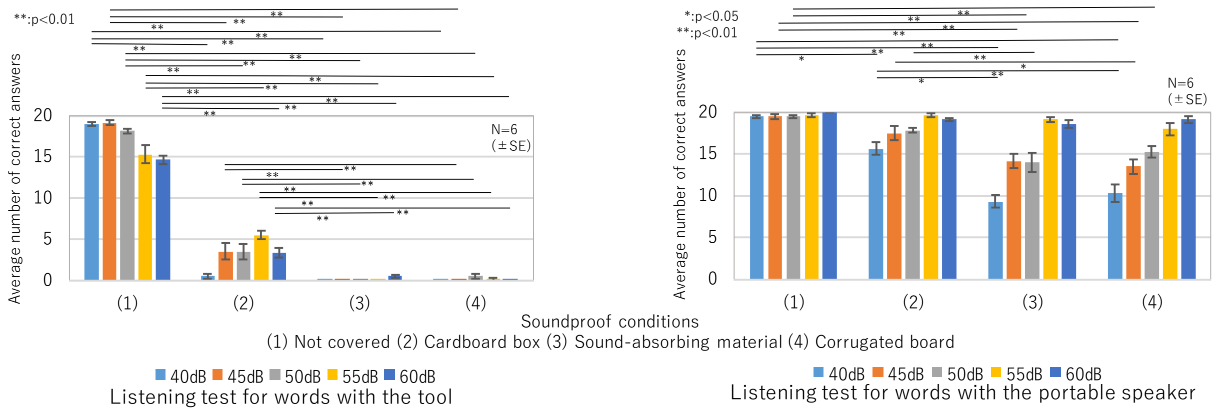

Figure 11. Average number of correct answers for the words listening test

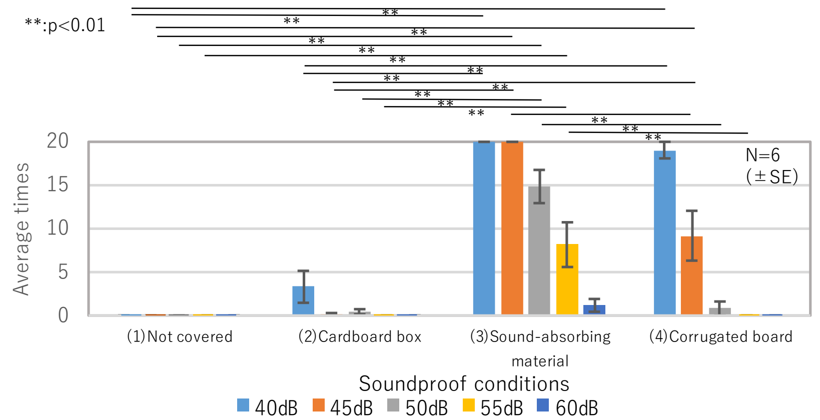

Figure 12. Average number of words that could not be heard at all with the tool

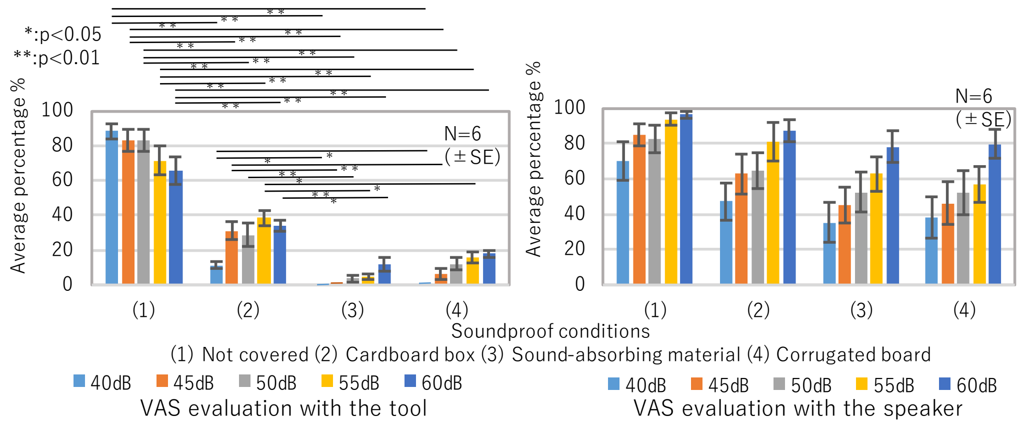

Figure 13. Mean values of ratings using VAS during the word listening tests

5. Consideration

It was found that the use of parametric speakers enabled the conveying of voice with reducing sound leakage to the surrounding environment. The conditions for using the tool are discussed based on the experimental results.

Figure 10 (2) shows that it is appropriate to use the tool under 45-55 dB output sound pressure, and Figure 10 (1) shows that the number of correct answers is relatively high, so considering the listener, it is appropriate to use the tool under 45-55 dB conditions. As for the effect on the surrounding people, as shown in Figure 8, the noise is reduced to a level close to that of the background sound by the sound-absorbing material used in the partition, and as shown in Figure 11, it is not audible as words under 40-55 dB conditions, indicating that sound leakage is extremely low.

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Even if the leaked sound is not audible as a word, Figure 12 shows that there may be a situation in which the sound is heard, which may bother the people outside the partition. Therefore, in order to reduce the presence of the sound at all, it would be effective to combine it with masking. Masking is a noise reduction method that makes the target sound inaudible by playing a sound with a higher sound pressure level than it. It is necessary to generate a louder masking sound when the target sound is loud. Using this tool can reduce the masking sound because the sound leakage to be masked will be decreased. Since it is difficult to use a large-scale facility in the environment envisioned in this study, the masking sound can be played near the ear using a smart phone. By combining this tool with masking, we can expect to realize a more effective system that takes advantage of both.
Finally, we will consider the development of a practical tool and its soundproofing capabilities. The maximum output volume can be as low as 50 dB, thus reducing the number of ultrasound generators that determine the output sound pressure of the tool. The further miniaturization of the tool also makes it possible to integrate it with the mask.

6. Conclusion

In a quiet environment such as a shelter or a hospital room, even a small noise attracts the attention of the people around, and the conversations often have to be carefully conducted. For this reason, we have developed a conversation support tool to alleviate the stress of all the speaker, listener and other people around them. In order to have a conversation with less noise to the surroundings, it is important that the speaker's voice reaches only the listener and that the speaker can understand it. In this study, we focused on the property that the higher the frequency of sound, the more likely it is to travel in a straight line. Therefore, we conceived the idea of a tool that converts audible voice into a highly directional ultrasonic range and delivers sound in a straight line to the listener's ear. The tool converts the audio input from the microphone into ultrasonic waves using a conversion circuit, and outputs them from parametric speakers. Since the reflectivity of ultrasonic waves propagating in the air is not greatly affected by the weight of the material used for soundproofing, even lightweight materials can be used for soundproofing. In this study, we used cardboard for soundproofing partition, which are considered to be easily available, assuming a shelter. To attenuate the sound, cottony newspaper was attached to the inside of the box as a sound-absorbing material. In the experiment, we played an audio file and confirmed that it could be used for conversation by having the subjects recognize the words. We also conducted a listening survey with soundproofing. From the experiment, it was confirmed that the sound was converted by the tool into a sound that could be shielded by cardboard, and that the sound leakage was reduced by soundproofing using cardboard and newspaper.

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