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Privacy protection method for speech using small speakers placed around a head

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ABSTRACT

One method of protecting speech privacy in public places, such as the waiting room of a pharmacy, hospital, or clinic, is to introduce a masking noise to the area. However, this method raises the overall noise level, which is undesirable. We propose a new method for protecting speech privacy without raising the overall noise level. In the proposed method, a masking noise is played from small speakers placed around the heads of listeners, and this protects privacy without raising the overall noise level in the room. In this experiment, various positions for the small speakers were considered on the basis of practicality and efficacy. The degree of masking provided by using small speakers was measured by a word intelligibility test. In addition, the noise level in the room was measured by a sound level meter. These experiments were carried out in a room arranged to simulate a pharmacy waiting room. The results indicated that the proposed method is suitable for protecting privacy without raising the noise level in the room and therefore offers a new method of protecting speech privacy.

Keywords: Speech privacy, Speech security, Sound masking, Small speaker
I-INCE Classification of Subjects Number(s): 51.1.5

1. INTRODUCTION

The waiting rooms of pharmacies, hospitals, and clinics are high-risk areas for the leakage of sensitive information. One privacy protection technique (1-4) for such areas is to add a masking noise (hereinafter, a masker) to the room so as to increase the difficulty of overhearing conversations between a doctor or pharmacist and patient. However, the problem with this method is that the masker raises the noise level in the room. As an alternative, we propose a new method for protecting speech privacy without raising the noise level in the room, where instead the masker is played over small speakers placed around the heads of listeners.

This study investigates the degree of masking and noise level distributions in the room and compares the results of the proposed method with those of the conventional method. The study also investigates whether the direction from which the masker arrives at the listener's ears influences the degree of masking.

2. EXPERIMENTAL METHOD

2.1 Test room and experimental devices

Figure 1 shows a schematic view of the room used to simulate a pharmacy waiting room during investigation of the masking effect. The test devices, described below, were placed in the test room with dimensions of 8.4 m × 10.8 m × 3.0 m (width × length × height).

As shown in Figure 1, speaker SP_1 (S-A4 SPT; Pioneer) played a conversation between a pharmacist and patient (the masked message), and speaker SP_2 (S-A4 SPT; Pioneer) played a masking noise (the masker), which is the masking conventional method. A listener sat 3.0 m from SP_1. In the proposed masking method, small speakers SP_R and SP_L (AT-SP102; Audio-Technica) were placed near the ears of the listener. The details of the positioning of SP_R and SP_L are described in Sections 3 and 5. All experiments were carried out in the test room.

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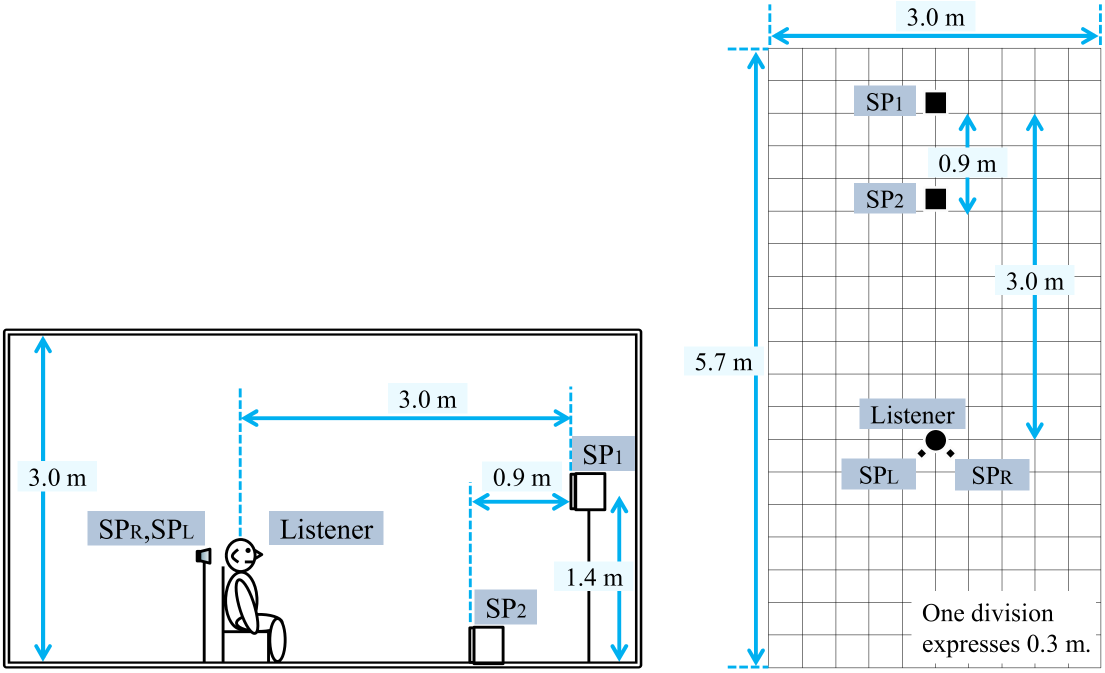

(a) Side view (b) Top view

Figure 1 – Schematic view of experiment

2.2 Test sound conditions

Speech sounds of words were used as the masked message. The words were chosen from the "NTT Database Series: Lexical Properties of Japanese (5)" and restricted to those with a familiarity of at least 5.5 and containing 4 mora (syllables). The masked message was played at 55 dB (A-weighted sound pressure level; hereinafter, dB(A)) near the entrance of the participant's ear canals. The level of the masked message (6) was decided to be reasonable for a conversation that would occur at a pharmacy. White noise (20–20000 Hz) was used as the masker.

3. WORD INTELLIGIBILITY TEST 1

This section describes the degree of masking of the conventional method and the proposed method.

3.1 Procedure

The degree of masking was measured by a word intelligibility test, where the word intelligibility score obtained is a percentage of correct answers: the lower the word intelligibility score, the stronger the masking effect. The participant was seated at the point shown for the Listener in Figure 1. As the masked message, the speech sounds of 10 words were played at 8 s intervals over SP1. As the masker, white noise was played by SP2 (in the conventional method) or by SPR and SPL placed near the participant's ears (in the proposed method). Figure 2 shows the layout of SPR and SPL. The masker was played at 60 dB(A) near the entrance of the participant's ear canals. Participants were asked to write any words they could hear under the experimental conditions. Seven participants (20 or 21 years old) participated in the experiment.

Figure 2 – Layout of small speakers

3.2 Results

Figure 3 shows the word intelligibility score for each experimental condition. The vertical axis is the word intelligibility score; the horizontal axis is the layout of speakers. The average word intelligibility score with the proposed method of masking was about 35%. This score was 15 points higher than the score for the conventional method. In a previous study (7), when the word intelligibility score was 35% or less, half of the people surveyed about waiting at a pharmacy felt that privacy was protected. Thus, the result of this experiment is that a sufficiently strong masking effect was obtained by the proposed method.

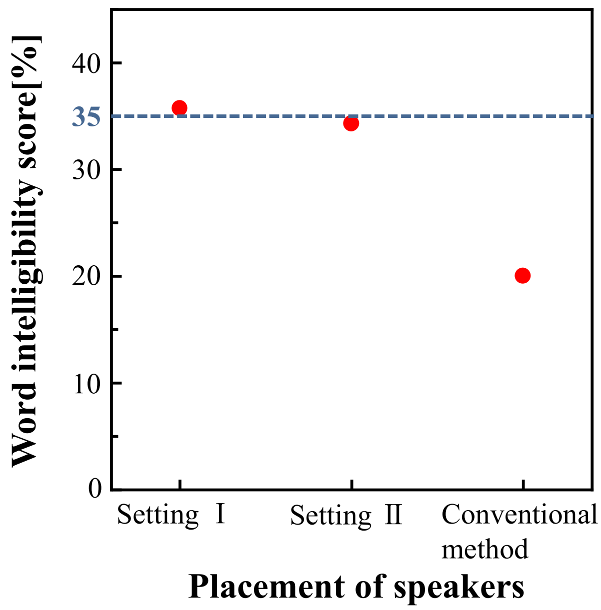

Figure 3 – Word intelligibility score

4. NOISE LEVEL DISTRIBUTIONS

Next, the noise level distribution was investigated for each method.

4.1 Procedure

The noise level distributions around a dummy head when the masker was played by each speaker were measured by a sound level meter (TYPE6226; ACO). The dummy head (KEMAR Type 45 BA; G.R.A.S.) with dummy ear auricles (KB0060-S1 and KB0061-S1; G.R.A.S.) was placed at the location of the Listener in Figure 1. The height of the dummy head was 1 m. As the masker, white noise was played by SP_2 (in the conventional method) or by SP_R and SP_L placed near the ears of the dummy head in Figure 2 (in the proposed method). The masker was played at 60 dB(A) near the entrance of the dummy head's ear canals. The measurement area is rectangular with grid intervals of 0.3 m (Figure 1 (b)).

4.2 Results

Figure 4 shows the noise level distributions in the room. When the masker was played by SP_2, the noise level in the measurement area was at least 58 dB(A). In contrast, when the masker was played over the small speakers, the noise level of the measurement area, except around the Listener, was at most 42 dB(A). The result indicates that the proposed method does not raise the noise level in the room when the masker is played.

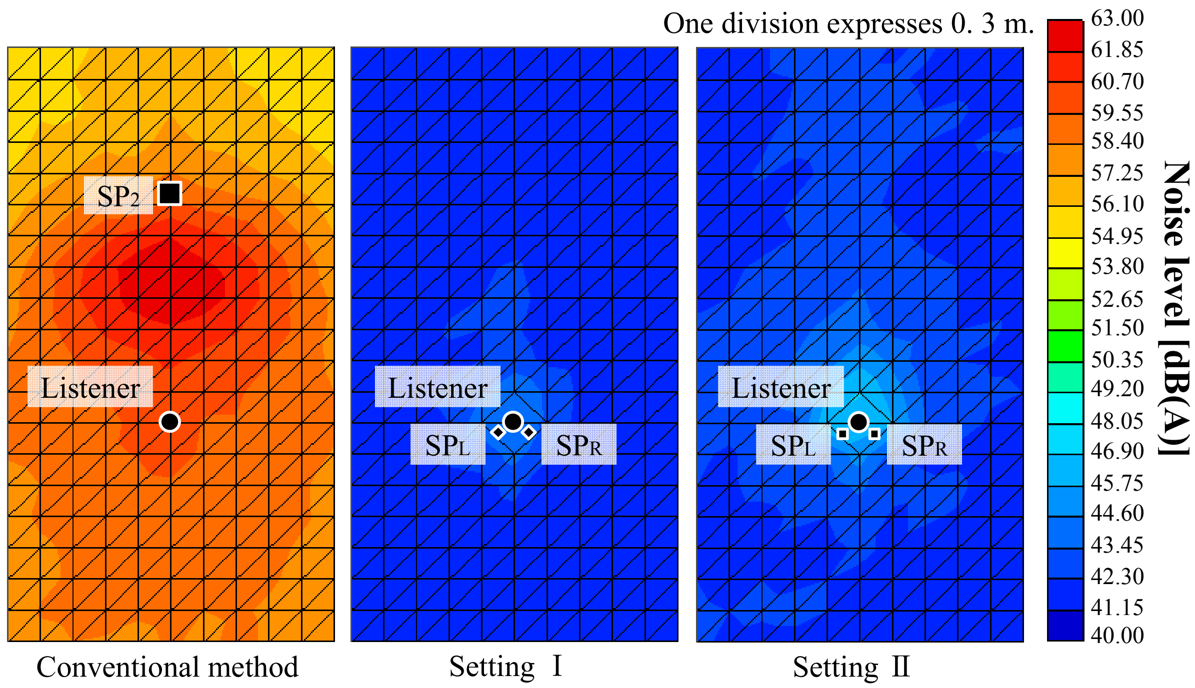

Figure 4 – Noise level distributions in measurement area

5. WORD INTELLIGIBILITY TEST 2

As discussed in Sections 3 and 4, a good masking effect can be obtained by the proposed method without raising the noise level in the room. This section describes an experiment to check whether the direction from which the masker is played in the proposed method influences the degree of masking.

5.1 Procedure

The strength of the masking effect was measured by a word intelligibility test (see Section 3) with the participants seated at the point shown for the Listener in Figure 1. As the masked message, the speech sounds of 20 words were played at 8 s intervals over SP1. As the masker, white noise was played over SPR and SPL placed near the participant's ears. Figure 5 shows the layout of SPR and SPL. The distance from each speaker to the entrance of the participant's ear canals was 0.05 m. The masker was played from various positions (Setting 1 to Setting 5 in Figure 5) over SPR and SPL, and the masker was equalized to the same subjective sound. The masker was played at 50, 55, and 60 dB(A) near the entrance of the participants' ear canals. In each trial, the participant wrote those words that could be heard under the above conditions. Twelve participants (22–24 years old) completed trials in the experiment.

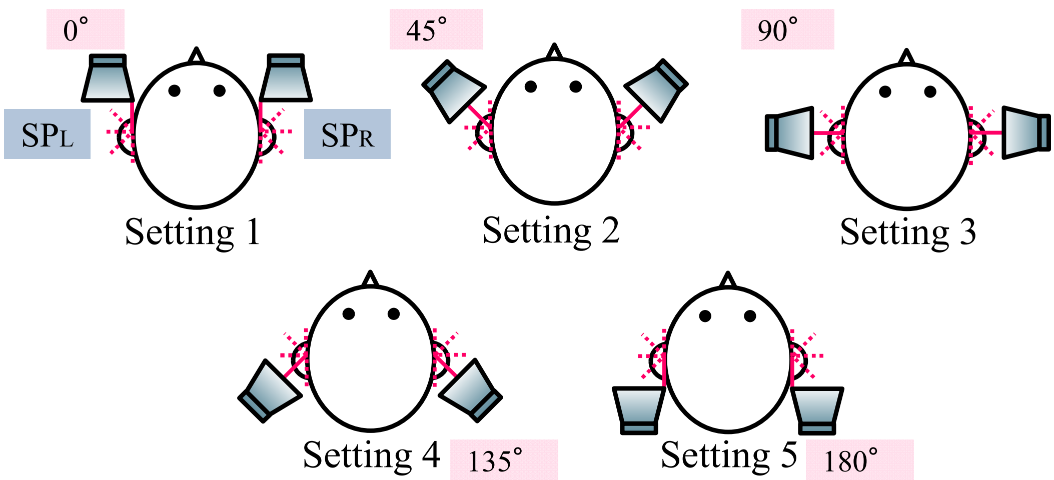

Figure 5 – Layout of small speakers

5.2 Results

Figure 6 shows the word intelligibility score in each experimental condition. The influence of the layout of SPR and SPL on the word intelligibility score of 10 participants was analyzed by ANOVA; the results from 2 participants were excluded as outliers (one above and one below). The results indicated that when the masker was at 55 or 60 dB(A), there was no influence of the layout of the small speakers on the word intelligibility score. When the masker was at 65 dB(A), however, the layout did influence the word intelligibility score, but there were individual-level differences ($p < 0.05$). However, the non-parametric Friedman-test showed no influence from the layout of the small speakers, regardless of masker level.

The following conclusions can be drawn from the above results.

(1) When the masker is played at 55 or 60 dB(A), the masking effect is weak, regardless of the layout of the small speakers.

(2) When the masker is played at 65 dB(A), the word intelligibility score is about 35% at most, regardless of the layout. This degree of masking is acceptable.

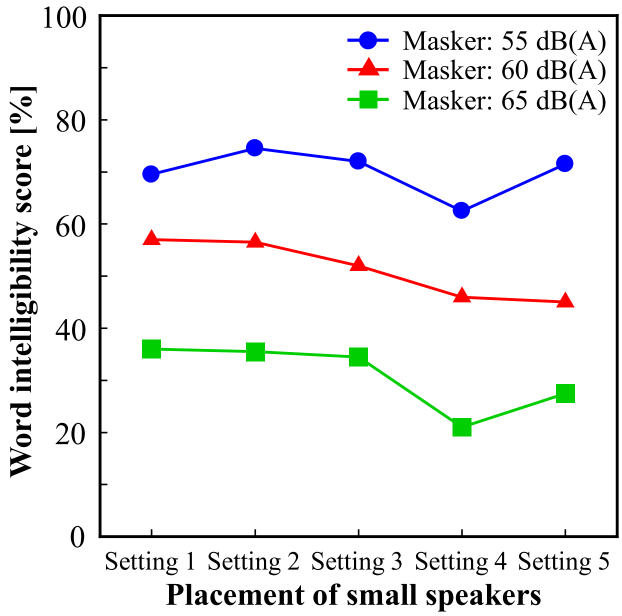

Figure 6 – Word intelligibility score

6. CONCLUSIONS

This study investigated the degree of masking and noise level distributions in the room when the conventional and proposed masking methods for privacy protection were used. The study also investigated whether the incoming direction of the masker influenced the strength of the masking effect in the proposed method. The following results were obtained.

(1) The proposed method is suitable for protecting privacy without raising the noise level in the room.

(2) The masking effect is acceptable even when the listener's head moves slightly and changes angle as long as a white-noise masker of 65 dB(A) is played near the entrance of the listener's ear canals.

Some unresolved details are to determine the optimal layout of the small speakers, to investigate alternative maskers, and to evaluate the psychological suitability of the method for practical use.

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