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Expression of the feelings to noise using cepstral parameters

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ABSTRACT

The influence that noise environment gives in human feelings becomes one important topics of the environmental problem. This paper shows the unpleasant feelings of human when hearing different type of noises. Previous our research showed that the unpleasant feelings are changed even if the sound pressure level hearing noise is same. In this paper, we define the feature parameters using spectral envelopes of noisy signal using cepstral coefficients. Relation between the feeling test of examinees and the feature parameters are compared. The results show that the spectral level on high frequency domain affect the feelings. Next, examination between the feelings and the Lombard effect are tested. The amount of the Lombard effect are defined using the center of the gravity of the pentagon by the first and the second formant frequency of Japanese 5 vowels or the average of the moving distance of the selected vowels. Examination shows some relationship between amount of the effect and feelings. The other experiments show that relationship between the kind of noise and feelings are tested and results are also shown.

Keywords: Feeling to sounds, Colored noise, Lombard effect, Cepstrum, Formant

1. INTRODUCTION

The influence of the environmental noise to the person is very important problem for social life. The feelings of noises affect to the safety life and it is considered that the detection of the quality of noises is important for this problem.

We measured the sound inside of the body using NAM microphones (1) and piezoelectric sensors to obtain the sleep in sleep-wake state (2). This paper showed that the noise from inside the body is changed when the examinees feel the sleepiness or comfortable. In sleeping state, the noise from the body made like the white noise. We measured the comfortableness of the human in this method and showed the effectiveness (3).

Lombard effect is known to happen when human pronounce a sound under the inferior noise environment. This effect is explained that improvement of intelligibility using the change of the pronunciation (4). Lombard effect is remarkable in poor noisy environment. The loudness of the utterance is increasing at the same time, and the uttering person feels unpleasantness.

We examined the Lombard effect under the noisy environment and showed the relationship between utterance of the vowels and the sound level of the noise (5). In this paper the Lombard effect is remarkable when examinees hear the white noise. And the Lombard effect is decreasing in case when examinees hear the pink noise even if the hearing sound pressure level is equal. These facts show that the Lombard effect is affected with the frequency features of the noises. These features are also concerned with the feelings of examinees. However, the relationship between the spectral feature of the noise and the Lombard effect is not clearly found.

In this paper, the Lombard sound using three kinds of the band noises are obtained. The shift of the formant frequencies and the difference of speech sound level is measured in case that the examinee is hearing several types of noises. We define the spectral feature parameter of the noise using cepstral coefficients obtained from noisy waveforms. We compare the feature parameters and the amount of the Lombard effect with the feeling test by examinees. The experimental results are shown in case the quality of the noise is changed. We also performed other set of the feeling test using these band the noises. Comparison between the feeling test and feature parameter in this experiments are also shown.

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2. THE EXPERIMENT OF RECORING LOMBARD SOUND

We recorded the Lombard voice using Japanese 5 vowels. Four Japanese male speakers speak the vowels while hearing the noise from headphone as shown in Figure 1. The source of the noise is obtained by audio check compact discs shown in Table 1. The spectral envelopes of noises are shown in Figure 2.

The level of the noise from headphone are determined as 60dB(A),73dB(A) and 85dB(A). Four examinees uttered 5 Japanese vowels while hearing these noises. In the experiment, examinees uttered voice as their pronunciation is able to be recognized.

Uttered speech sounds are sampled by sampling frequency 10 kHz and quantized by 12bit. The speech data analyzed into 25 cepstral coefficients using improved cepstral method (6). In analysis, frame period is 10ms and the frame length is 25.6ms. Spectral envelopes of vowels are obtained from these 25 cepstral coefficients and formant frequencies are calculated by detecting local peaks of the spectral envelopes of the center part of vowels.

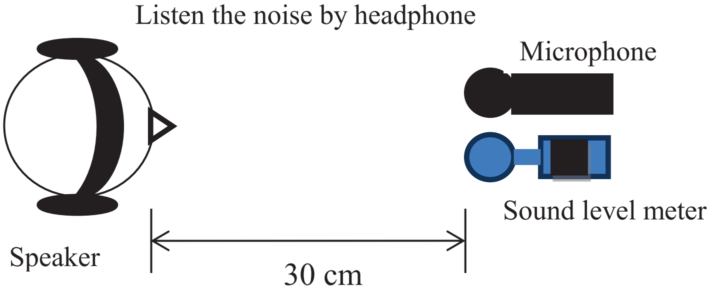
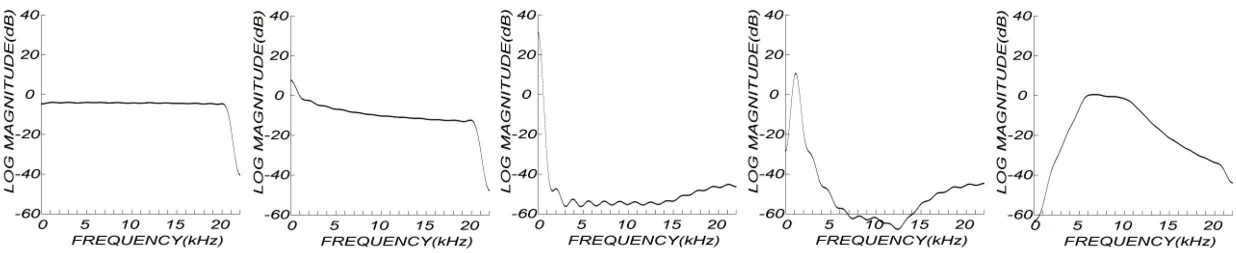


Figure 1 – Example illustration of the recording the Lombard sounds

Table 1 – Source of the noise waveforms used in this experiment

Noise or Equipment	Source
Headphone	SONY MDR-480AV
White noise	DENON CD COCQ-84695 Track 10
Pink noise	DENON CD COCQ-84695 Track 11
Band noise 125Hz/1kHz/8kHz (1/1 oct.)	DENON SACD COGQ-28 Track 9-11



(a) (b) (c) (d) (e)

Figure 2 – Spectral envelope of the noise used in this experiment
(a) white noise (b) pink noise (c) band noise 125Hz
(d) band noise 1kHz (e) band noise 8kHz

3. THE SHIFT OF THE FORMANT FREQUENCIES BY LOMBARD EFFECT

The results of the difference of the Lombard effect when examinees hear different types of noises. Table 2 shows that the sound level of the vowels when examinees pronounced with hearing noises. The results show that the sound levels of the pronounce vowels are affected to the noise in territory below the frequency 1 kHz.

The Lombard effect of the vowels is measured using the distribution of the first and the second formant frequencies of the uttered vowels. Figure 3 shows the first and the second formant frequencies when examinees hear the white noise and the pink noise. In Japanese, the distribution of the first and the second formant is known to become the pentagon when the turn of the vowel is /i/, /e/, /a/, /o/, /u/ like Figure 3. This figure also shows that the movement of the formant frequency is increasing when examinees hear the louder noise.

The movement of the formant frequencies is caused by the change of the shape of vocal tract when the examinees utter the loud voice. We measure the shift of the formant frequencies by Lombard effect using the movement of the center of gravity of the pentagon (5). The movement of the pentagon is expressed in Figure 4. We define the variation of the center of gravity as equation 1, where the coordinates of the first and the second formants before movement and after movement are represented as (F_{A1}, F_{A2}) and(F_{B1}, F_{B2}).

$$F_{AB} = \sqrt{(F_{B1} - F_{A1})^2 - (F_{B2} - F_{A2})^2} \quad (1)$$

The moving distances of the coordinate of the center of the gravity of pentagons are shown in Table 3. This results show that the movement is concerned with the power of the spectral envelopes of noises on low frequency domain and the movement becomes large when the hearing noise level beyond 73dB(A).

Table 2 – Relationship between the hearing noise level and the sound level of voice (dB(A))

noise level	61dB(A)		73dB(A)		85dB(A)	
vowel	/a/	/i/	/a/	/i/	/a/	/i/
white noise	91	82	93	88	101	92
pink noise	93	84	97	92	102	95
band noise (125Hz)	90	80	97	87	100	92
band noise (1kHz)	89	80	93	82	98	90
band noise (8kHz)	90	78	90	79	93	84

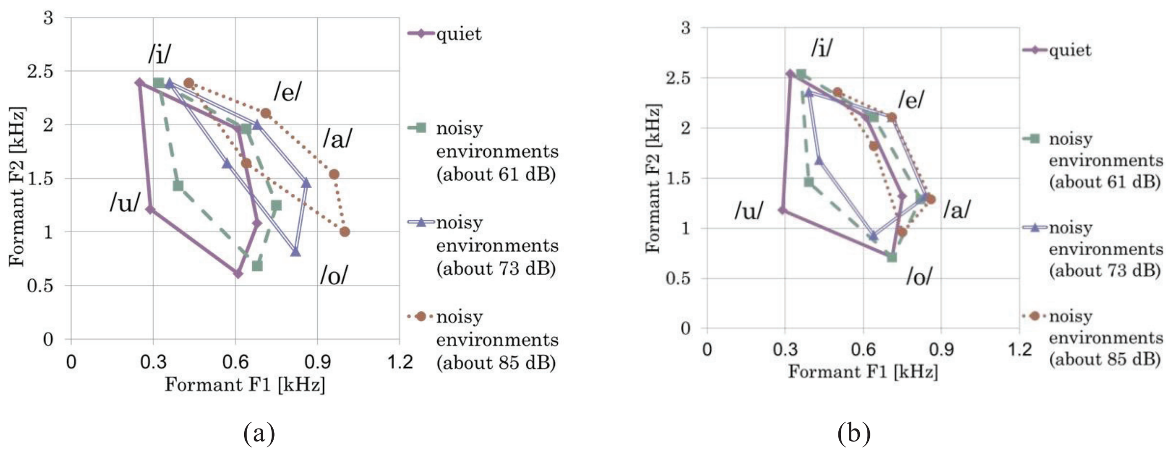


Figure 3 – Example illustration of the first and the second formant frequencies of Japanese 5 vowels in case that examinee is hearing the noise (Speaker A)
(a) white noise (b) pink noise

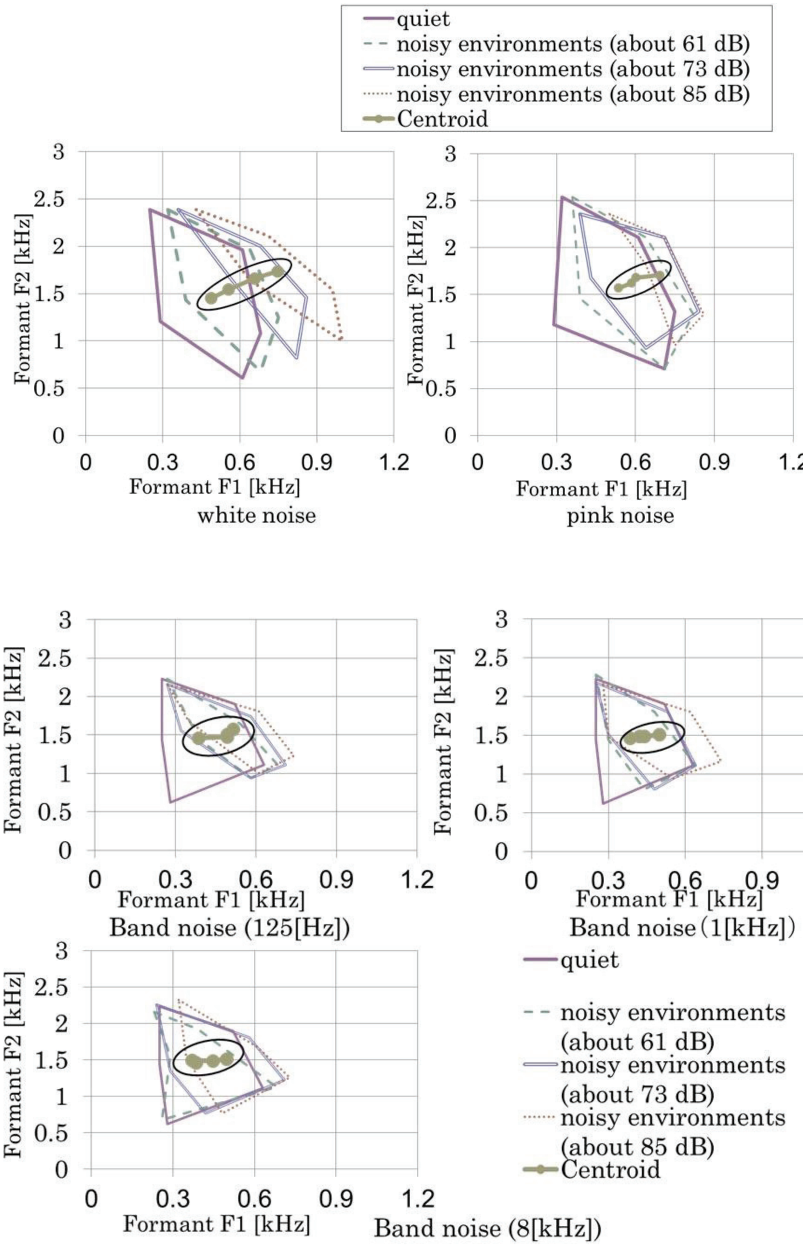


Figure 4 – Movement of the centroid of pentagon by the first and the second formant of Japanese 5 vowels caused by Lombard effect (Speaker A)

Table 3 – Moving distances of the center of the gravity of the pentagon by formant frequency

	Quiet to 61dB(A)	61dB(A) to 73dB(A)	73dB(A) to 85dB(A)
white noise	0.114	0.158	0.115
pink noise	0.069	0.058	0.080
band 125Hz	0.107	0.004	0.061
band 1kHz	0.044	0.014	0.064
band 8kHz	0.032	0.034	0.067

We define the spectral feature parameter of the noise using cepstral coefficients of the noisy signals. The summation of the first cepstral coefficients to the nth cepstral coefficients are defined as equation 2, which express the broad inclination of spectrum. In this equation, c_i^{ν} indicates the ith cepstral coefficient at ν frame.

$$P_{\nu} = \sum_{i=N}^{M} c_i^{\nu} \qquad (2)$$

This parameter expresses the value of spectral envelopes at zero frequency expressed by M cepstral coefficients. In this paper, N=1 and M=15 is used. The value of the parameter becomes small in case that the noise level is decreasing on high frequency domain. The Figure 5 shows the value of parameters when noisy waveform change. It is found that and the amount of the parameter is concerned with Lombard effect.

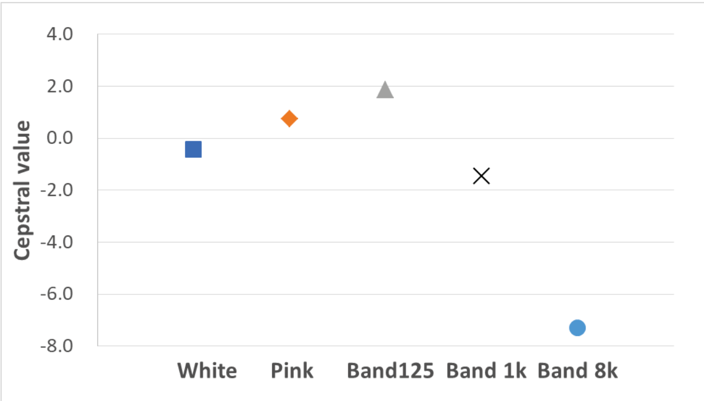


Figure 5– The spectral feature parameters of noises by cepstral coefficients

(Cepstral order 1 to 15)

We have another test for detecting of the preference of the noisy tone using 11 examinees. Each examinee heard the 5 kinds of the noise of the same pressure level. The examinee put number one on the noise felt most unpleasantly and put 5 on the noise felt least unpleasantness. The result is shown in Table 4 and this result shows that the unpleasantness is related with the amount of the Lombard effect. However, in the test the standard deviation in case of the band noise 8kHz is large and there are different taste patterns are seen. Further preference test may be required to investigate the relation with the amount of Lombard effect.

Table 4 – Results of the preference score using five types of noises (60dB (A))

	White noise	Pink noise	Band noise 125Hz	Band noise 1kHz	Band noise 8kHz
Average ranking	2.09	2.45	2.55	4.27	3.64
Standard deviation	0.99	0.79	2.79	0.56	1.50

4. CONCLUSIONS

In this paper, the Lombard sounds obtained from five types of noise are measured to detect the influences of the frequency features of the noises. The previous our report suggested Lombard effect is concerned with the noise on high frequency domain. The experiments in this paper showed that the band noise which has large level on lower frequency domain affect the Lombard effect. And the feature parameters by cepstral coefficients of noises are defined and we found out that a defined parameter is correlated with the Lombard effect. The hearing test of noisy waveforms showed that the some relationship between the Lombard effect and the feelings to noise. However, there are large deviations at the test using 8 kHz band noise and further hearing test will be required.

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