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SUBJECTIVE EFFECT OF HVAC NOISE ON MUSIC PLAYERS

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ABSTRACT
As a study on subjective effect of HVAC noise on music players, experimental investigation was made using an artificial simulated sound field. For the experiment, an electro-acoustic simulation system using six channel loudspeakers to reproduce the sound field of a concert hall and HVAC noise was constructed in an anechoic room. The HVAC noises with various spectrum characteristics were presented to two professional music players and annoyance impression was examined. As a result, it has been indicated that the noise level should not exceed 30 dB(A) and the noise spectrum influences on annoyance besides the noise level. Especially, tonal components were judged highly annoying for performance.

1 - INTRODUCTION

In concert hall acoustics, auditory impression of the player is essentially important as well as that of the audience. On this point, we have studied on the effect of several acoustic attributes such as early reflections [1] and long-path reflections from the audience area [2]. As another topic, we are now making experimental study focusing on the effect of HVAC noise as one of the essential requirements of concert halls. In this paper, subjective tests on professional music players performed in an artificial simulated sound field are presented.

2 - EXPERIMENTAL SYSTEM

Figure 1 shows the diagram of the experimental system. To realize the natural impression as actually being on a stage, a 6-channel reproducing system was employed. Original acoustic data were recorded through a directional microphone (Sony C48) set toward six directions corresponding to the six loudspeakers.

HVAC noises were simulated by the system A in which the six channel recording data of noises in various spaces were recorded and reproduced through level controllers. To reinforce the low frequency components, one woofer was added.

The hall sound, the acoustic effect of a concert hall such as reflections and reverberation was simulated by the system B consisting six channel real-time convolution systems. To get the filter coefficients in the convolvers, impulse responses were measured on a stage as follows. A dodecahedral omnidirectional loudspeaker simulating the instrument was set on a representative point on the stage. The directional microphone was set at a close point to the sound source and the directional impulse responses were measured for the point by rotating the microphone as shown in Fig. 1. The six directional responses excluding direct sound and a reflection from the floor during three seconds were installed in the convolvers. Both signals from the systems A and B were mixed and reproduced from each loudspeaker set in the respective direction.

3 - SUBJECTIVE TEST

3.1 - Experimental method

The subjective test was performed on a professional violin player and a piano player. As the input signal to the System B, the direct sound of the violin detected by a directional microphone (Sony C48) was

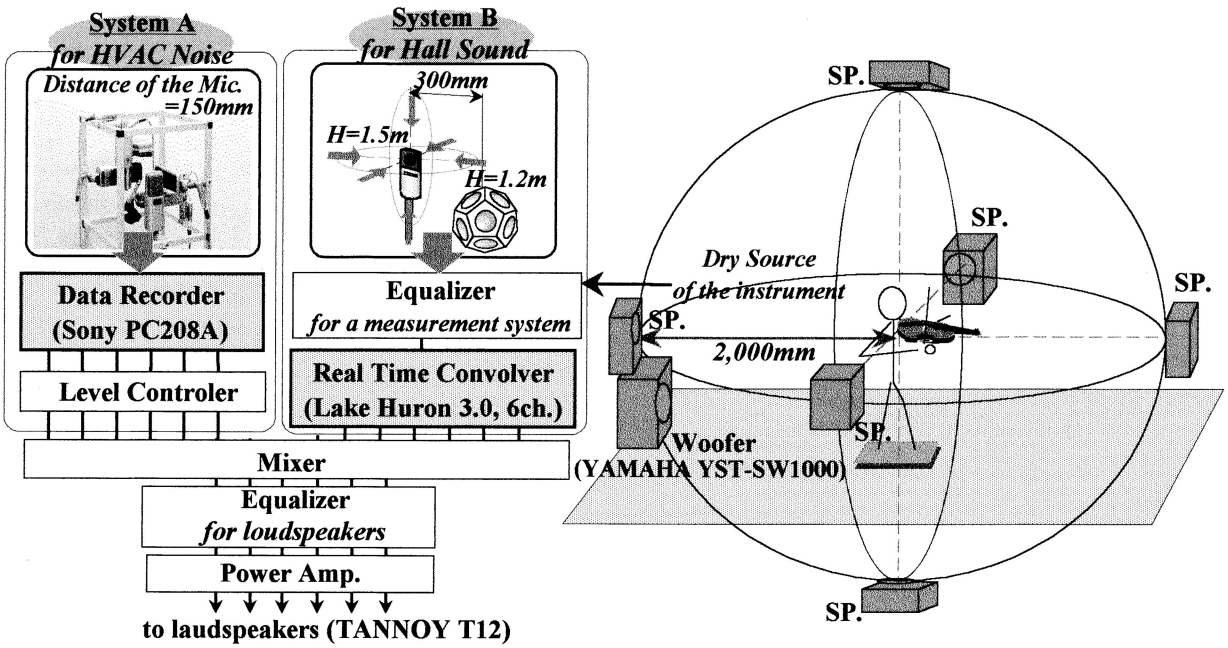

Figure 1: Diagram of the experimental system.

used. In case of the test on the piano player, an electric piano was used and the electric output signal of the instrument was fed to the System B. A loudspeaker set close to the piano reproduced the direct sound of the instrument. In the experiment, the condition of the hall sound was fixed for each player so that he/she can get the natural impression as playing on a stage.
Figure 2 shows the spectra of the HVAC noises used in the test. Table 1 shows five indices calculated from these spectra. Using these sounds, two experiments were performed, (1) by using spectrum A, in 12 steps at intervals of 2 dB(A), and (2) by using four kinds of spectra A to D in the constant level of 30 dB(A).

	L_A [dB(A)]	LL(Z) [sone]	NC	RC	NCB
Spectrum A	30	1.29	21 / 8k Hz*	27 / 63 Hz	25 / 8k Hz
Spectrum B	30	1.06	23 / 63 Hz	33 / 63 Hz	25 / 63 Hz
Spectrum C	30	1.28	24 / 1k Hz	25 / 1k Hz	24 / 500 Hz
Spectrum D	30	0.98	23 / 250 Hz	26 / 250 Hz	25 / 250 Hz

Table 1: Noise indices calculated from the test sounds of the HVAC noises (*/Hz: the center frequency in one octave band, which determines the criteria).

Under each condition, the subject stayed at the center point of the experimental field, played various types of pieces imagining that he/she was playing on the stage of a concert hall and judged the degree of annoyance of the noise by category as follows: "In the case of playing, surrounding noise is 1) Not annoying at all, 2) A little annoying, 3) Very annoying, 4) Extremely annoying." Besides, the subject made free comments about the noise. It took about 3 to 5 minutes to evaluate each experimental condition.
In case of the violin player, annoyance impression was different according to the performing style. That is, the judgement was rather severe when imaging solo playing and a string quartet, whereas when imaging piano accompaniment or concerto with orchestra, the judgement was relatively permissive. Regarding the piano player, the judgement was done by general impression though he commented that the annoyance had changed by the number of the codes, volume, tempo, and music motif.

3.2 - Experiment 1

The relationship between the noise level and the subjective evaluation was examined for spectrum A, which is typical as HVAC noise. The noise level was set within 22 dB(A) to 44 dB(A) in 2 dB(A) steps and presented to the subject. The judgments were done in descending series and ascending series. The averaged scores of both series (one time each) are shown in Fig. 3. A comparison between the results

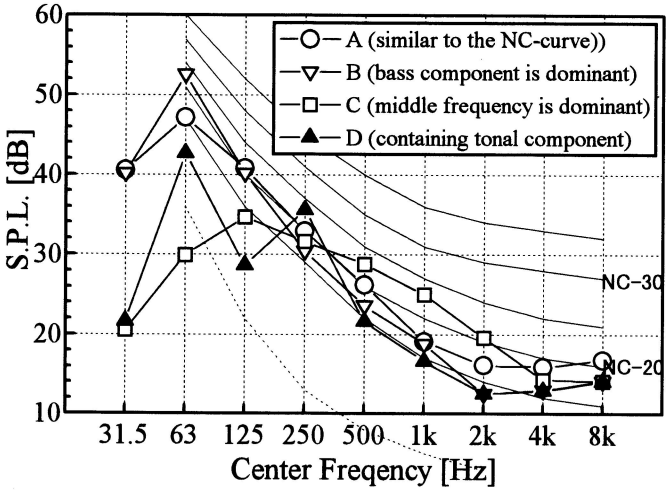

Figure 2: Spectrum characteristics of the HVAC noise.

of the two players shows that the acceptable level for the piano player tends to be higher than that for the violin player by about 5 dB(A). From the results, the condition of 30 dB(A) is supposed to be a critical level at which the violin player, whose judgement was relatively strict, commented that it was not severely annoying though the presence of the noise was sensed.
As another result indicated in this experiment, the players do not necessarily prefer the condition of the lowest noise level. The violin player said, "In the condition without noise completely, it is oppressive and uncomfortable. When subtle noise is sensed (in the condition of 24 to 26 dB(A)), it is rather natural and preferable." In the condition below about 26 dB(A), the piano player commented, "It is like in a recording studio and unnatural as in a concert hall."

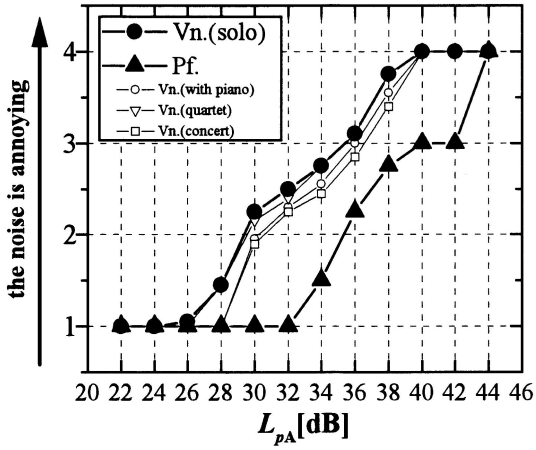

Figure 3: Results of the experiment for the level.

3.3 - Experiment 2

To examine the effect of the spectrum characteristics, four kinds of spectra (A to D in Fig. 2) were tested under the condition that the levels were fixed for each player, 30 dB(A) for the violin player, 35 dB(A) for the piano player, respectively. Table 2 shows the judgement of annoyance and comments by the subjects. In comparison between four types of spectra, spectrum A (it is close to the NC-curve) and spectrum C (the middle frequency is dominant) are relatively acceptable. On the other hand, the condition with a dominant bass component (spectrum D) can be felt unpleasant in some cases. Further, it was shown that the noise containing tonal components (spectrum D) was judged highly annoying by both players. In this case, the dominant frequency causing the impression is 315 Hz in one third octave band.

	Violin player	*Piano player*
Spectrum A	(1.8) "This kind of noise is not so annoying nor irritating."	(2) "It is not irritating."
Spectrum B	(2) "The low noise makes my heart beat. It is always heard when playing. I will ask to stop the HVAC system."	(1.5) "It is heard in low frequency and less irritating than that with high frequency. It seems to be better than A"
Spectrum C	(2) "It is hardly heard when the notes are in high frequency though it is sensed in the pause or the silent parts."	(2) "It is not so disturbing because the noise does not conflict with the sound of the piano."
Spectrum D	(4) "This strange tone is always heard in background. It is very annoying and makes my pitch wrong. It must not exist. It must be stopped."	(2.5) "The certain pitch is clearly heard. It makes discord in the week note and attenuating part. It prevents me to concentrate on playing."

Table 2: Results of the experiment on the difference of spectra ((): the judgments of annoyance in the category; the comments of Vn are that in imaging solo).

4 - CONCLUSIONS

From the results of the subjective experiments on two music players, it has been indicated that the noise level should not exceed 30 dB(A) (or NC-20) when the spectrum is neutral. Besides, not only the noise level but also the noise spectrum might change the impression of players. Especially, the tonal components must be strictly prevented as it is judged highly annoying when the player sensed a pitch in the noise.

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