

Reproduced sound pressure level yielding the maximum auditory presence: Further study on effects of reproduced SPLs on auditory presence

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1. Introduction

The authors have investigated the property of auditory presence [1–5] where “presence” corresponds to the Japanese word “rinjōkan” [6]. For example, it was shown that five factors are involved in auditory presence, i.e. factors of aesthetic state, volume, softness, information on sound, and sound localization [3]. Although the previous report [5] demonstrated that auditory presence changed as a function of reproduced SPL (Sound Pressure Level), a specific condition that yielded the maximum presence was not identified. Further considerations on the condition are undertaken in this report.

2. Experimental method

2.1. Outline of experiment

In our previous report [5], eight materials composed of sounds and moving pictures were prepared and the auditory presence of each material was examined by varying its reproduced SPL in 5- to 8-dB steps in most cases. This experiment is hereafter referred to as EXP 1. The experimental results indicated that auditory presence tended to reach a maximum near the original SPL of each material except for materials which had sound sources that moved with the listener. Despite this clear tendency, it was difficult to specify the SPL that yielded the maximum presence since the variation step of SPL was rather large. In order to identify the specific SPL conditions, an experiment with smaller variations of 3- to 4-dB steps was required. Five of the eight materials that showed a distinct tendency in EXP 1 were employed as stimuli in the experiment reported here, which is termed EXP 2. Table 1 shows the five materials.

These materials with a duration of 15 s were composed of sounds and their corresponding moving pictures as mentioned above. The sounds were binaurally recorded via a dummy head (Koken, SAMRAI) and the moving pictures were recorded using a digital video camera (Panasonic, DJ-100) in live situations. The moving pictures were presented using a 50-inch display (Sony, KL-X9200J) located 5 m away from a subject so that the reproduced angles of the visual fields were the same as the original fields. The sounds were presented to the subject via headphones (Stax, SR-Lambda). Prior to reproduction, the frequency-response characteristics of the

outer ears of the dummy head were rectified through digital signal processing to avoid duplicating the characteristics in recording and reproduction [7].

2.2. Procedure of EXP 2

EXP 1 was conducted under two conditions: “without pictures” in which only sounds were presented and “with pictures” in which sounds were presented with their corresponding moving pictures [5]. The procedure of EXP 2 was the same as that of “with pictures” in EXP 1 except the variation steps of SPLs were different. Thus, separate experiments were conducted for the five materials using Scheffé’s method of paired comparison modified by Ura [8]. Five or six sounds, whose SPLs were changed in 3- to 4-dB steps, were prepared for each material. Two sounds, randomly selected from these sounds, were sequentially presented to the subject with its corresponding moving picture. The subject compared the two sounds (namely, *A* and *B*, in the presentation order) in terms of their auditory presence. They were instructed to rate the sound on a seven-point category scale (from “−3” to “+3”). One end (−3) corresponded to the case when sound *A* had a much higher presence than sound *B*. The other end (+3) was the opposite case and the midpoint (0) was when both *A* and *B* had equivalent presence. The number of comparisons for each material was 20 ($= {}_5P_2$) or 30 ($= {}_6P_2$) since every possible permutation was presented to cancel time order errors.

Nine male and two female subjects, between 21 and 23 years of age, with normal hearing acuity participated in the experiments. The subjects also participated in EXP 1.

3. Results and discussion

To derive the relative auditory presence for the five or six sounds of each material, a scaling procedure was separately applied to the data for each material. Figure 1 shows the relative auditory presence obtained in EXPs 1 and 2, respectively.

The results of EXP 1 that are relevant to EXP 2 are briefly discussed. In the previous report [5], the results of seven subjects were shown separately due to the tested order of the two conditions. Since distinct differences were not observed in the condition of “with pictures” regardless of the order, all the data was merged in this report. Here the results of new subjects were also merged so that the results between EXPs 1

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and 2 can be compared. The merged results shown in Fig. 1 agree well with the previous report [5]: although the auditory presence seems maximized at a higher SPL than the original one, it is difficult to identify a specific SPL because the

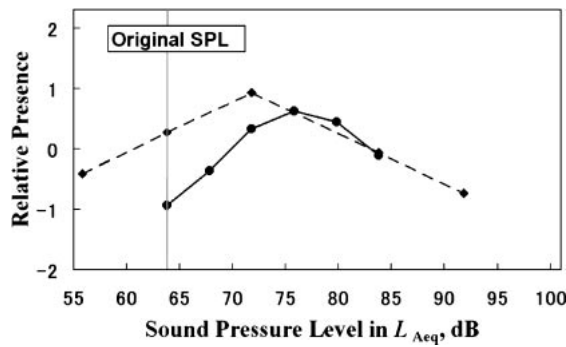
Table 1 Materials used as stimuli in EXP 2. Their SPLs in the original sound fields are denoted in L_{Aeq} (dB). Values in parentheses indicate the distances between the sound source and the recording point.

Primary sound involved in the material	L_{Aeq}
sound of a train passing (approx. 150 m)	63.8
sound of a train passing (approx. 1 km)	62.8
murmuring of a stream (2 m)	76.7
murmuring of a stream (50 m)	69.7
roaring of a waterfall (approx. 20 m)	82.4

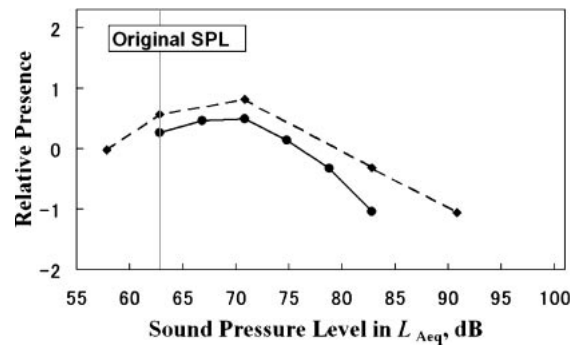
variation step was rather large.

As for EXP 2, it is noteworthy that the presence data of the two experiments cannot be quantitatively compared since the data for each experiment is denoted on relative scales. In other words, only tendencies as a function of SPL can be compared. As shown in Fig. 1, the tendencies of the each experiment coincide well. Moreover, the results of EXP 2 clearly show that the reproduced SPL at the maximum presence was higher than that in the original field.

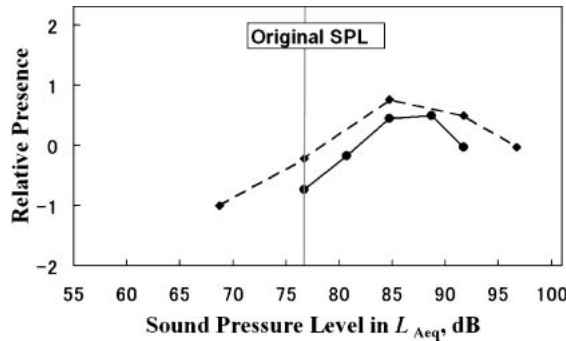
The reason for this tendency is considered below. When a subject listens to a sound with its corresponding moving picture, the primary criterion of auditory presence seems to be whether the loudness of the sound matches the moving picture. Thus, the presence results in a single-peaked pattern as a function of SPL, which indicates that the factor of information on sound involved in auditory presence [3] is dominant: correct information must be given to a listener so



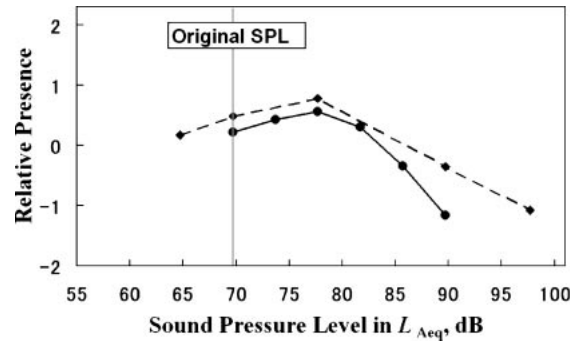
(a) sound of a train passing (approx. 150 m)



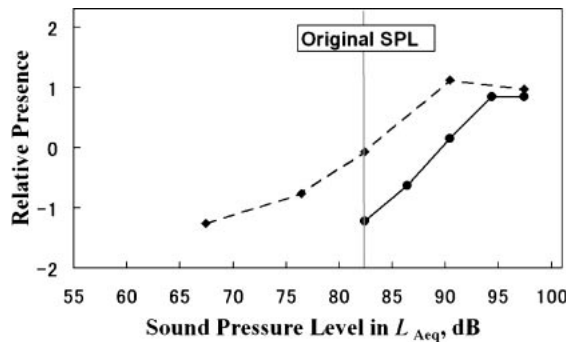
(b) sound of a train passing (approx. 1 km)



(c) murmuring of a stream (2 m)



(d) murmuring of a stream (50 m)



(e) roaring of a waterfall

Fig. 1 Relative auditory presence as a function of reproduced SPL. Broken and solid lines indicate the results of EXPs 1 and 2, respectively.

that he/she can naturally image the original scene. However, near the original SPL, there is probably a permissible SPL range in which a listener can accept a combination of a given sound and a moving picture as natural. In the range, the criterion might be that a more powerful sound yields a higher presence due to the volume factor [3]. In order to verify this idea, the differences between the original SPL and the SPL yielding the maximum presence are examined. Comparing Figs. 1(a) and 1(b), and Figs. 1(c) and 1(d) indicates that the SPL that yields the maximum presence becomes higher than the original SPL if the distance between the sound source and the recording point is smaller, which results in a larger visual angle of the sound source. Moreover, as shown in Fig. 1(e), the SPL at the maximum presence is more than 10 dB higher than the original one for a waterfall with a large visual angle. These findings suggest that the permissible SPL range shifts higher, i.e. louder sound becomes acceptable as natural, if a given picture evokes an image of “a loud sound source.”

4. Summary

When a sound is presented to a listener with its corresponding moving picture, the SPL that is higher than the original one yields the maximum auditory presence. This tendency is explained by psychological factors involved in auditory presence.

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References

- [1] K. Ozawa, Y. Chujo, Y. Suzuki and T. Sone, “Effects of contents and methods of reproduction on the auditory presence,” *Proc. Autumn Meet. Acoust. Soc. Jpn.*, pp. 611–612 (1999).
- [2] K. Ozawa, Y. Chujo, Y. Suzuki and T. Sone, “Contents which yield high auditory-presence in sound reproduction,” *Kansei Eng. Int.*, **3**, 25–30 (2002).
- [3] K. Ozawa, Y. Chujo, Y. Suzuki and T. Sone, “Psychological factors involved in auditory presence,” *Acoust. Sci. & Tech.*, **24**, 42–44 (2003).
- [4] K. Ozawa, S. Ohtake, Y. Suzuki and T. Sone, “Effects of visual information on auditory presence,” *Acoust. Sci. & Tech.*, **24**, 97–99 (2003).
- [5] K. Ozawa and M. Miyasaka, “Effects of reproduced sound pressure levels on auditory presence,” *Acoust. Sci. & Tech.*, **25**, 207–209 (2004).
- [6] R. M. V. Collik, K. Hinata and M. Tanabe, Eds., *Kenkyusha's New College Japanese-English Dictionary* (Kenkyusha, Tokyo, 1995), p. 1966.
- [7] K. Abe, K. Ozawa, Y. Suzuki and T. Sone, “Evaluation of environmental sounds using adjectives describing sound quality, emotional state, and information carried by sounds,” *J. Acoust. Soc. Jpn. (J)*, **54**, 343–350 (1998).
- [8] S. Ura, “An analysis of a paired comparison experiment,” *Qual. Control — J. JUSE*, **16**, 78–80 (1959).