Directional Dependence of the Change of Auditory Source Width by Very Short Time-Delay Reflections

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Abstract: This paper investigates the effect of the direction of lateral reflections on the decrease of ASW when the time delay of reflections are very short relative to the direct sound. The psychoacoustical experiments were conducted in an anechoic chamber using the constant method. The experimental results demonstrate that the decrease of ASW depends on the direction of the reflections. As the reflections arrive from a more frontal direction, the decrease of ASW becomes larger.

INTRODUCTION

Auditory source width (ASW) is one of the most important factors in the subjective evaluation of concert halls. ASW is defined as the width of an auditory event perceived temporally and spatially to be fused with the auditory event of a direct sound (1). One of the physical measures to evaluate ASW for the music motif is the degree of interaural cross-correlation (DICC) measured by using a KEMAR dummy head without artificial ear simulators and A-weighting. It has a negative correlation with ASW (2). However, Barron (3) showed that spatial impression (SI) corresponding to ASW decreases gradually as the time delay of reflections, relative to the direct sound, become shorter than 10ms, even though the level of reflection is constant. This might be caused by an inhibition of the reflection level in the auditory system. Moreover, the measured DICC is constant independent of the time delay of reflections, too. Therefore, DICC measured (considering the temporal weighting which corresponds to the inhibition) must have a negative correlation with ASW. Considering the real sound fields, however, there are many reflections and their directions are different. This paper makes it clear whether the decrease of ASW depends on the direction of reflections with a very short time delay or not.

EXPERIMENTAL METHOD

The method of constant was employed in these experiments using the paired comparison test between the test field and the comparison field. The subjects were asked to judge which sound field had a wider ASW. The music motif used in this experiment was a 6.5sec section from bar 94 of the 4th movement of Mozart’s Jupiter Symphony (No.41), which was the same motif as that used by Barron. The sound fields used as stimuli consisted of a direct sound and two discrete reflections with a 1ms interval between them. The directions of the reflections were ±18°, ±45° and ±72°. In the test fields, the levels of reflections relative to the direct sound were fixed at -8dB. The time delays of the first reflection relative to the direct sound were 2, 4 and 8ms. In the comparison fields, the time delay of the first reflection was fixed at 20ms. The level of reflections were variable. The binaural sound pressure level (4) of stimulus measured using the KEMAR dummy head was constant at 70±0.5dBA. Three male students acted as subjects.

EXPERIMENTAL RESULTS AND DISCUSSION

At first, the percentage by which ASW of the comparison field was wider than that of the test field was obtained for each subject and each test field. Furthermore, the z-transformation of the percentage was performed. The correlation coefficients between the z-value and the level of reflections of the comparison field exceed 0.896 for all test fields. This means that the distribution of responses by any subjects to any test fields could be regarded as a normal distribution. Then, the regression equation was obtained by the least-squares method. The mean value of the reflection levels relative to the direct sound at which ASW for the comparison field is equal to that for the test field and the standard deviation are derived from the regression equation. Figure 1 shows the results as a
function of the time delay of the first reflection of the test field. Open circles are the mean values for $\pm 18^\circ$, filled circles for $\pm 45^\circ$ and triangles for $\pm 72^\circ$. The values at 20ms in these figures are the reflection level of the test field. The experimental results demonstrate that the contribution of reflections to ASW decrease as the time delay of reflections becomes shorter for all directions of reflections. However the decrease of ASW depends on the direction of the reflections. Judging from the standard deviations, it can be considered that the decrease of ASW is equal for all directions for delays $> 4$ms since the mean values for $\pm 18^\circ$ are included in the standard deviations for $\pm 45^\circ$ and $\pm 72^\circ$. Such behavior can also be seen for $\pm 45^\circ$ and $\pm 72^\circ$ except for subject A at 4ms for $\pm 18^\circ$. However, for the 2ms time delay, the mean values for $\pm 18^\circ$ are not included in the standard deviations for $\pm 72^\circ$ for any subjects. Namely there is a difference between the rate of decrease of ASW for $\pm 18^\circ$ and that for $\pm 72^\circ$. These results indicate that the rate of decrease of ASW depends on the direction of reflections. Therefore, it is impossible to use the same weighting for all directions. However, DICC which is weighted by the rate of the decrease for the more frontal direction might be enough to evaluate ASW in practical use, because reflections $< 2$ms come nearly from the direction of the direct sound in existing halls.

![Figure 1](image)

**FIGURE 1.** The reflection levels of the comparison fields at which ASW for the comparison fields is equal to that for the test field obtained are plotted as a function of the time delay of the first reflection of the test field. Open circles are mean values for $\pm 18^\circ$, filled circles for $\pm 45^\circ$ and triangles for $\pm 72^\circ$.

**CONCLUSION**

For the sound fields with very short time delay reflections, the decrease of ASW increases as the reflections arrive from a more frontal direction, even though the level of reflections is constant. For the 2ms time delay, there is a difference between the rate of decrease of ASW, while there is no difference at all between all directions for delays $> 4$ms.

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**REFERENCES**