The influence of direction of late arriving sound on listener envelopment

Y.J. Choi, N. Higa and K. Fujimoto
Kyushu-university, Dept.of Architecture, Fukuoka, Japan.

H. Furuya
Kyushu Kyoritsu-university, Dept.of Architecture, kitakyushu, Japan.

The purpose of this study is to make clear that the relationship between the directional properties of late arriving sound and listener envelopment (LEV). Psycho-acoustical experiments are performed with an objective measure of inter-aural cross-correlation(IACC) in order to predict whether LEV is perceived equally in two kinds of sound fields with horizontal or vertical component of late arriving sound. It is found that LEV is affected by not horizontal component of late arriving sound but also vertical one.

1. Introduction

Listener envelopment(LEV), which is an important factor in the subjective measurement of concert halls, is usually affected by the lateral reflections sound energy. On the subjective judgement of LEV, those objective measures were used : the lateral energy fraction(Lf), the lateral energy efficiency(LE), the inter-aural cross-correlation(IACC), and the relative level of the late arriving lateral sound energy(LG).

However, early studies had tended to these objective measures were mostly obtained using two dimensional sound fields. So It is not sure that whether these objective measures have application to three dimensional sound fields or not. In the judgments of spatial impression(SI) with objective measures are must examined using two kinds of sound fields with horizontal or vertical component of late arriving sound; One is called horizontal sound fields and the other is called vertical sound fields.

Therefore, in this paper , continue to the author`s previous work[1) ,new subjective experiments using two kinds of sound fields simulated in an anechoic room are performed and to compare of perceived LEV with each kind of sound fields.

2. Method

A total of two experiments were conducted using simulated sound fields in an anechoic chamber. Depending upon the experiment 13 loudspeakers were used to radiate sounds that consisted of a simulated direct sound and late arriving sounds. Using programmable digital reverberators and equalizers, the experi-

mental setup allowed independent contr-control of angular distribution of the late arriving sound send to each loudspeaker.

All tests were in the form of adjustment by subject and the subject was asked to equate two sound fields ,One is called fixed sound fields and the other is called variable sound fields, with regard to LEV by controlling the level of the variable sounds fields with late arriving sound. Using an attenuator, subjects could toggle between the two sound fields of each pair as many times as they wished until they had decided on their response.

Fig.1 illustrates the signal configuration used as stimulus. The onset of the late arriving sound was delayed by 80ms (relative to the direct sound) and they were directly delivered to the left loudspeakers and to the light loudspeakers with a time delay of 10ms. The reverberation time(RT) is 1.8s.

The stimulus used for all of tests was an anechoic orchestral recording consisting of the 10s of Bizet`s Menuet de suite No.2 "L`Arlesienne". Five students ,22 to 29 years of age with normal hearing sensitivity, acted as subjects for both tests and there was always a short practice session before each test to ensure that the subjects were familiar with the requirements of each test.

Acoustical conditions of fixed sound fields for each test are shown in Table I .

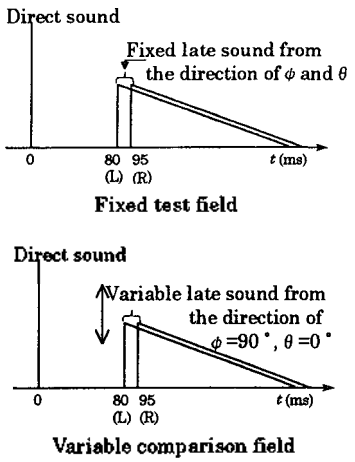

Fig.1 Signal configuration used as stimuli

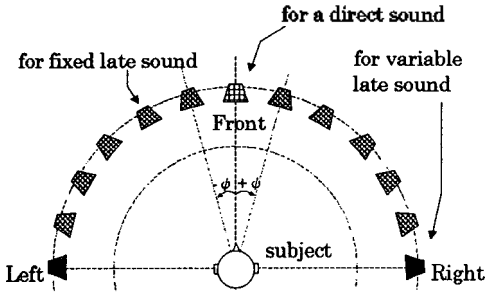

Fig.2 Arrangement of loudspeakers in Exp.1

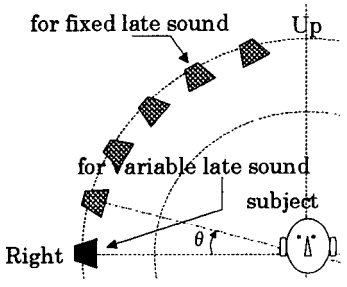

Fig.3 Arrangement of loudspeakers in Exp.2

On judgements of LEV, ICC(Without A-weighted) which is calculated impulse response obtained using a dummy head was used. In this Table, ICC_0^{∞} and ICC_{80}^{∞} are respectively defined as that ICC_0^{∞} (the total sound) is when t_1=0 and t_2 =500s and ICC_{80}^{∞} (the late arriving

sound) is when t_1=80 and t_2 =580s. Loudness were obtained by BL[2] (binaural level), using a sound pressure level with dummy head. L_{Aeq} by music was adjusted throughout each test an average level of approximately 62 dBA.

3. Experiment1

The first experiment was intended to show how sound fields which consists of horizontal late arriving sounds affects on LEV. Five subjects listened to pairs of sound fields with regard to LEV and were asked to equate. So the test was repeated four times per each subject, thus in total, subject made 20 experimental results.

The sound fields consisted of five pairs of late arriving sound whose angle attribution is that $\phi = \pm 15°$,30° , 45° , 60° , 75° as shown in Fig.2.

The results of the experiment are given in Fig.4 with the mean scores of ICC and the 99% confidence limits which was measured by dummy head(Neumann KU100). These results show that, subject regard ICC(without A-weighting) as one of objective measures on judging LEV and also lateral component of late arriving sound is more attributable to the LEV.

4. Experiment 2

The second experiment was intended to show how sound fields ,which consists of vertical late arriving sounds, affects on LEV. The sound fields consisted of five pairs of late arriving sound whose angle attribution is that $\theta = \pm 15°$,30° 45° , 60° , 75° as shown in fig.3.

Table 1 Acoustical conditions of fixed test field.

ϕ	ICC_0^∞	ICC_{80}^∞	C_{80}(dB)	BL(dBA)	L_{Aeq}(dBA)
15°	0.922	0.486	−3.2	64.5	62.5
30°	0.808	0.263	−3.1	64.7	62.6
45°	0.751	0.244	−2.7	65.0	62.8
60°	0.744	0.219	−2.6	65.0	62.3
75°	0.734	0.261	−1.8	65.2	62.0
θ	ICC_0^∞	ICC_{80}^∞	C_{80}(dB)	BL(dBA)	L_{Aeq}(dBA)
15°	0.705	0.211	−1.9	65.6	60.5
30°	0.731	0.238	−2.2	65.4	61.0
45°	0.760	0.275	−2.7	65.1	61.3
60°	0.807	0.317	−2.8	64.6	61.5
75°	0.879	0.499	−3.5	65.0	61.3

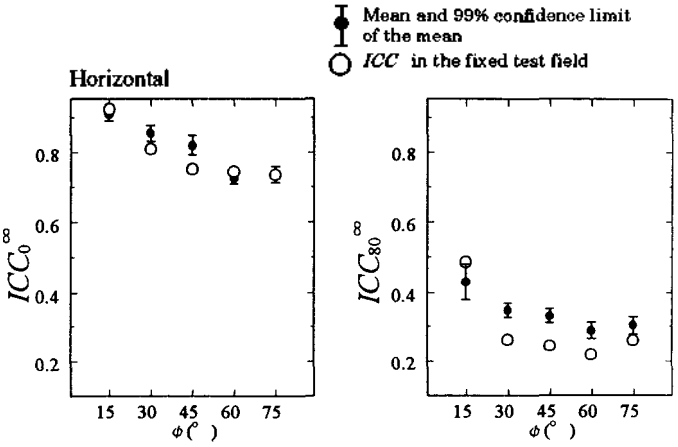

Fig.4 Relation between ICC and ϕ (°)

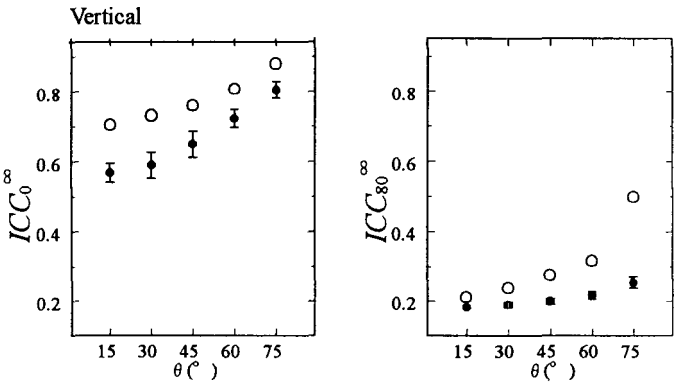

Fig.5 Relation between ICC and θ (°)

The results of the experiment are given in Fig.5. with the mean scores of ICC and the 99% confidence limits. These results indicate that vertical component of late arriving sound may be attributable to judging LEV, because there is a linear relationship between ICC and angle distribution of late arriving sound as much as horizontal one. Accordingly, both horizontal and vertical component of late arriving sound are important factors on judging LEV.

5. Conclusions

In according to the results of this study, LEV is affected by similarly in both horizontal and vertical component of late arriving sounds. Also, in this paper so simple sound fields were used to predict LEV. It is considerable things that judgement of LEV, with the more complicated sound fields and objective measures except ICC.

6. References

1)K.Ohnishi, K.Fujimoto, H.Furuya, "Effect of direction of reverberation on listener envelopment," Research meeting of AIJ Kyushu chapter (Environment).37,41-44 (1998).

2)W.Robinson, L.S.Whittle, "The loudness of directional sound fields," Acustica, Vol.10 74-80(1960).