Subjective Diffuseness in Loudspeaker Systems With Height

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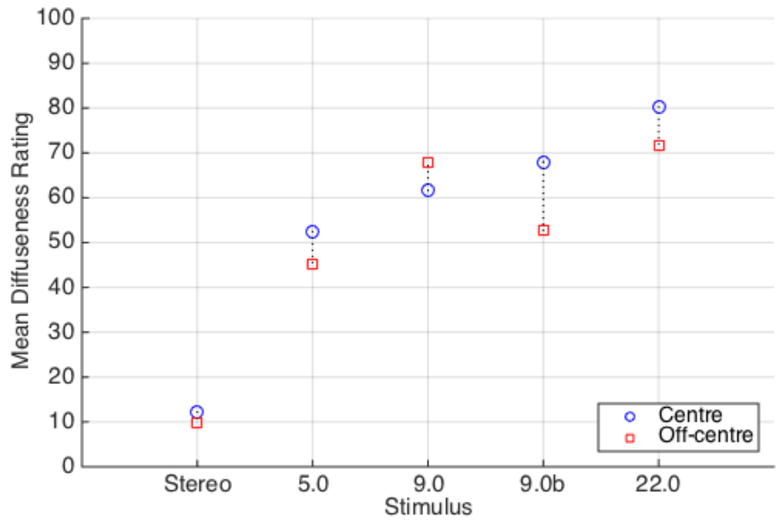
Introduction

A MUSHRA-style listening test was used to determine how different factors affected the perceived diffuseness using uncorrelated pink noise stimuli and a range of loudspeaker layouts. A preliminary experiment used an adjustment task to optimise the relative level between loudspeakers at head-height and loudspeakers not at head-height (the Inter-Subset Level Difference (ISLD)). Optimising the ISLD ensured that elevated loudspeakers added to a 2D layout were neither too loud or too quiet. The optimal ISLD (only measured on centre) was dependent on the loudspeaker layout and was one factor investigated in this experiment. A centre and an off-centre (80cm right of centre) listening position were included for most stimuli (with a red square). The experiment was conducted by 16 listeners (11 following post-screening) in the Audio Lab at the University of Southampton.

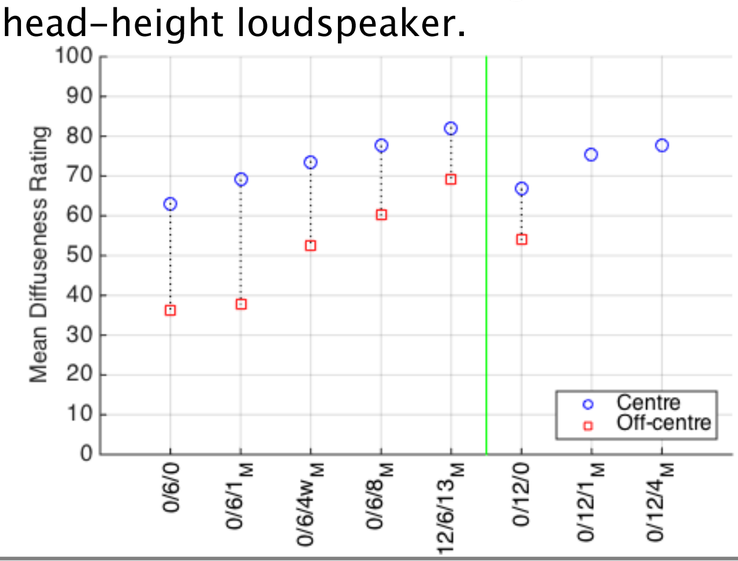
Standard Layouts

Standardised layouts perform as expected with more loudspeakers perceived as more diffuse. Although 9.0 appears more diffuse off-centre than on-centre, the two positions required separate MUSHRA trials so may be less comparable than stimuli in the same listening position.



Number of Non-Head-Height Loudspeakers

Increasing the number of non-head-height channels increases perceived diffuseness even when there are 12 head-height loudspeakers (assumed to be a perceptual maximum in 2D) even using only one non-head-height loudspeaker.



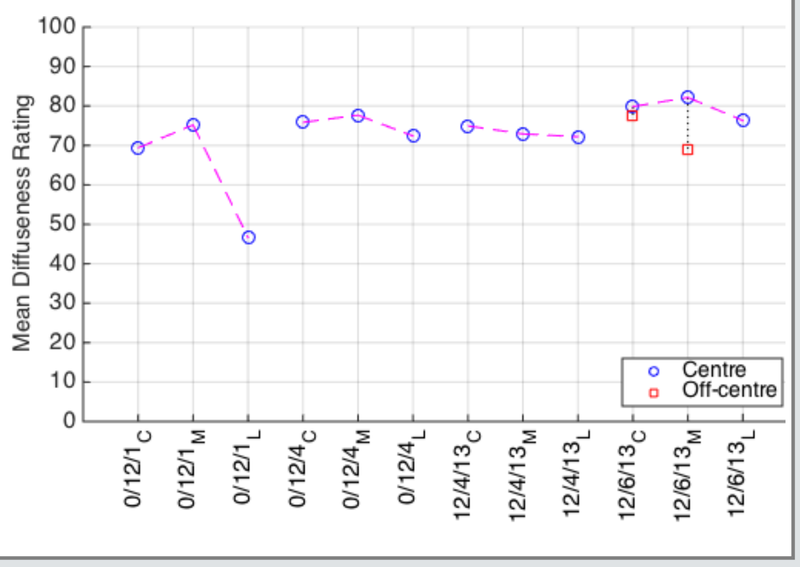
Inter-Subset Level Difference (ISLD)

Each 3D layout can be divided into a head-height subset and a non-head-height subset. The level difference between these subsets is the ISLD. If the gain of the head-height subset is *X* and the gain of the non-head-height subset is *Y*, then the combined level of both subsets (*T*) is constant but the ISLD is the difference which can be any value.

$$X = 10\log_{10}(s)$$
$$Y = 10\log_{10}(1-s)$$
$$T = 10\log_{10}(s+(1-s)) = 0\text{dB} \qquad ISLD = 10\log_{10}(s/(1-s)) \qquad 0 \le s \le 1$$

A preliminary experiment was conducted to find the optimal ISLD that maximised the perceived diffuseness for different loudspeaker arrangements. The mean adjusted ISLD from the preliminary experiment (**subscript M**) was compared to two other level distributions to validate the preliminary experiment and test the increase in perceived diffuseness. **Subscript C** indicates all the loudspeakers are at the same level. Therefore, the ISLD depends on the number of loudspeakers in both subsets. **Subscript L** indicates equal loudness from both subsets (*X*=*Y*, *ISLD*=0) and the ISLD is independent of the number of loudspeakers.

The optimised level distribution was found to be more diffuse or as diffuse as the other level distributions. Maintaining equal loudness from each individual loudspeaker (*C*) is nearly as perceptually diffuse as the optimised ISLD. Equal subset level (L) is significantly less diffuse. In the only layout investigated off-centre, 12/6/13, the optimised level distribution is not the most diffuse. The ISLD used in both listening positions is that of the central listening position where the head-height loudspeakers are 3.5dB louder in $12/6/13_M$ than in $12/6/13_C$. The louder head-height loudspeakers become easier to localise off-centre and the perceived diffuseness decreases.



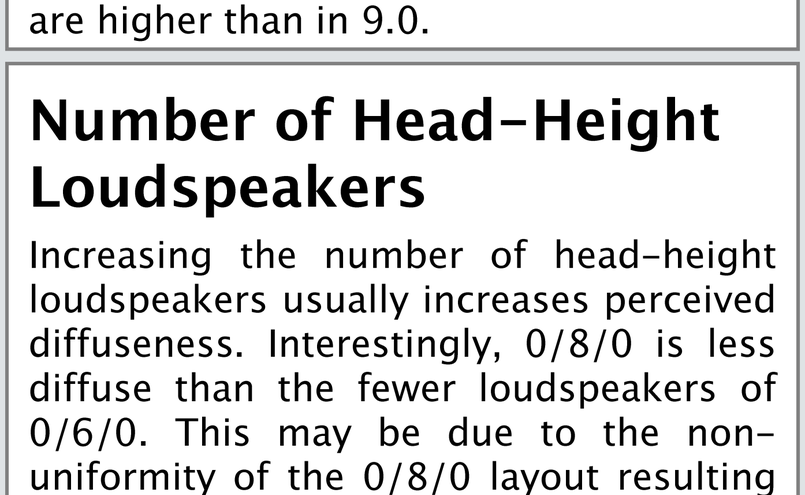
labels: $b/n/a_i$ or **standard layout labels**

a and ***b*** are the number of loudspeakers in layers above and below the head-height layer respectively. ***n*** is the number of loudspeakers at head-height. ***i*** is one of three ISLD choices which relates to the relative level between the head-height loudspeakers and the non-head-height loudspeakers.

Standardised layouts are ITU-R standards except the height loudspeakers in 9.0b are higher than in 9.0.

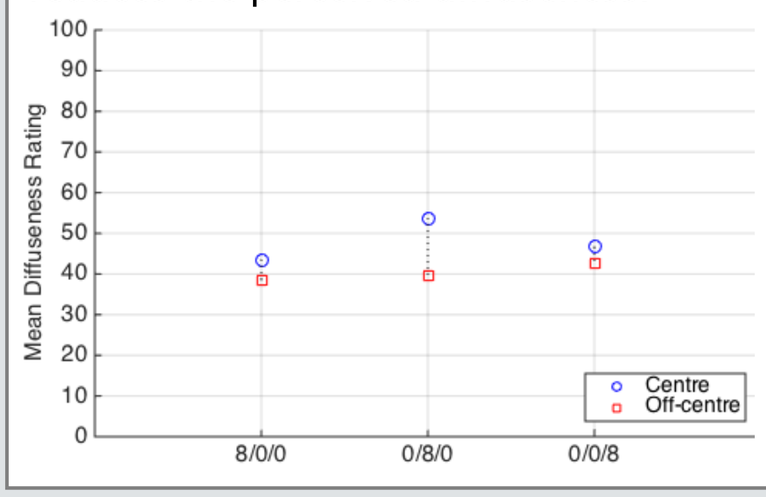
Number of Head-Height Loudspeakers

Increasing the number of head-height loudspeakers usually increases perceived diffuseness. Interestingly, 0/8/0 is less diffuse than the fewer loudspeakers of 0/6/0. This may be due to the non-uniformity of the 0/8/0 layout resulting from resource constraints. The rating may be higher if an even distribution of 8 loudspeakers was used. Diffuseness is increased even when 25 non-head-height loudspeakers are used.



Elevation of a Horizontal layer of Loudspeakers

A head-height layer is perceived as more diffuse than placing the layer above or below head-height. Off-centre the preference for the head-height layer height is negated because the loudspeaker nearest the listener is closer in 0/8/0 than the other two. This near loudspeaker is then easier to localise and reduces the perceived diffuseness.



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