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**SIMULATIONS AND SUBJECTIVE RATING OF ACOUSTIC
CONDITIONS IN A SYMPHONY ORCHESTRA
- A CASE STUDY**

Summary

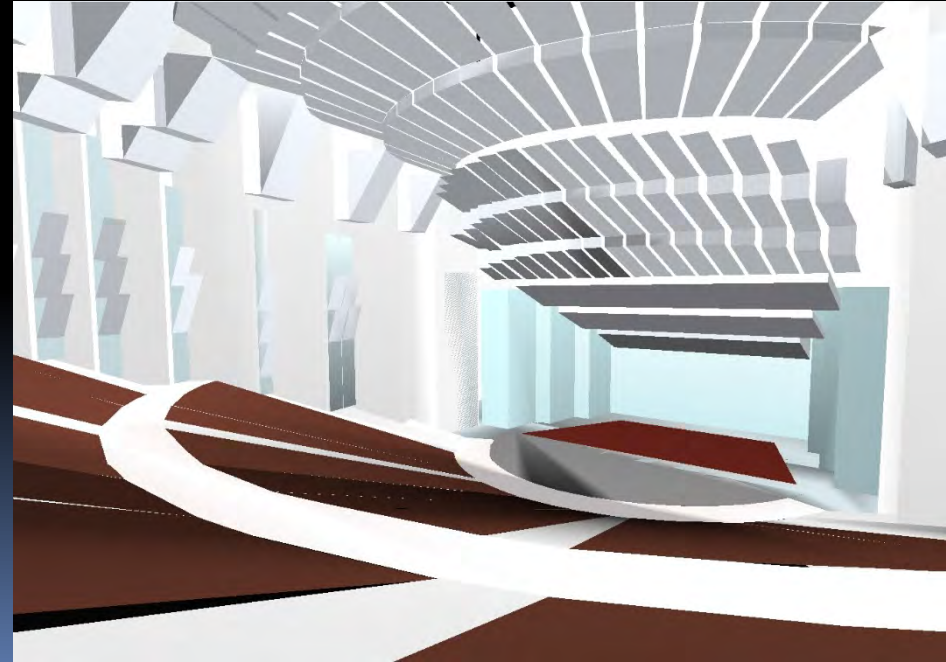
- Subject: Acoustic conditions in a symphony orchestra on concert hall stage
- Occupied conditions very different from empty stage conditions
 - Sound is absorbed, reflected, obstructed and diffracted by musicians, chairs, stands and instruments
- Occupied conditions easier to simulate than to measure
- Case study of inter-orchestral sound transmission:
 - 1 symphony orchestra, 8 familiar venues: concert halls, rehearsal hall and pit
 - Subjective rating (N=50) of the 8 venues
 - Simulated conditions in 3D-models (Odeon) of the 8 venues
 - Comparison: Simulated conditions vs subjective rating
 - Many metrics tested for correlation with subjective rating, r^2 ranged from 0.09 to 0.85
 - Result: Inter-orchestral sound-transmission average Gd-Gr ≈ 0 \leftrightarrow average D-R ≈ 0
 - Interpretation: Orchestra preferred a balance between direct and reverberant sound
 - Implication: Fraction of co-musicians inside/outside critical radius is a critical factor

Domestic venues

Concert hall



Computer model (Odeon)



Domestic venues

Orchestra pit in concert hall

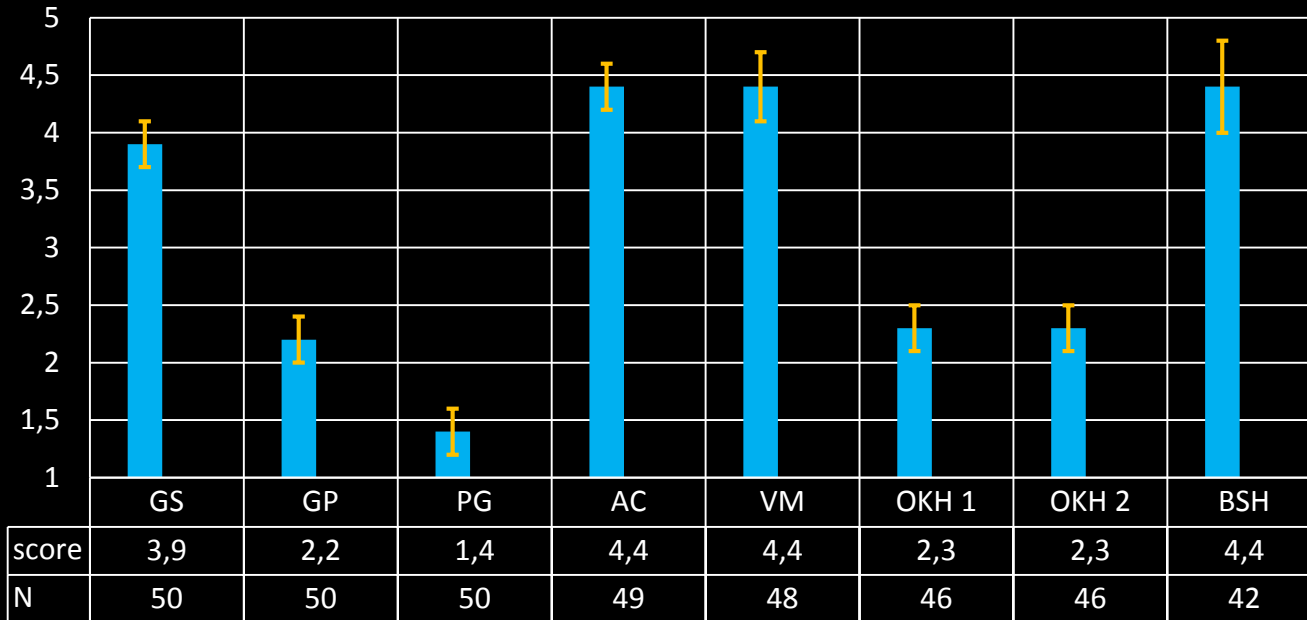


Rehearsal in multi-purpose hall

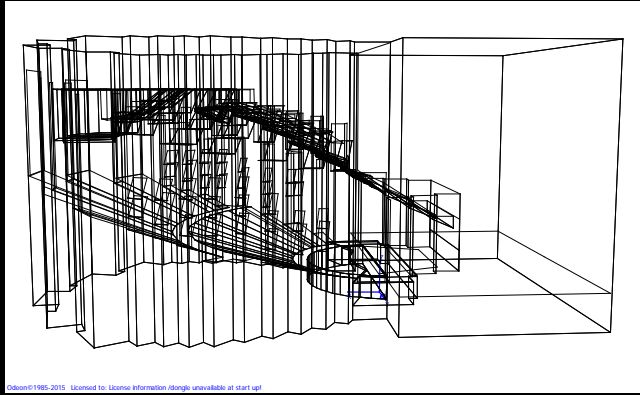


Overall preference 8 venues

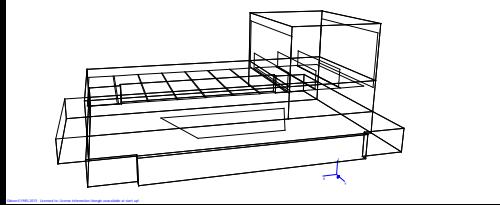
Average preference in 95% confidence intervals



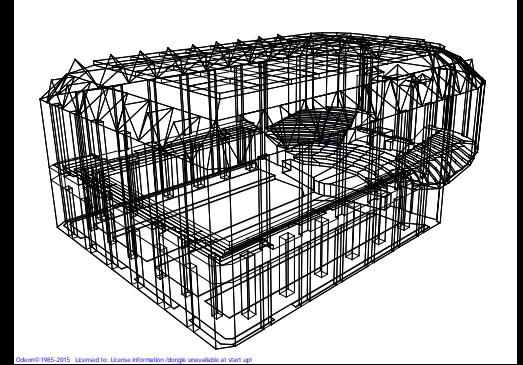
3D models of the venues



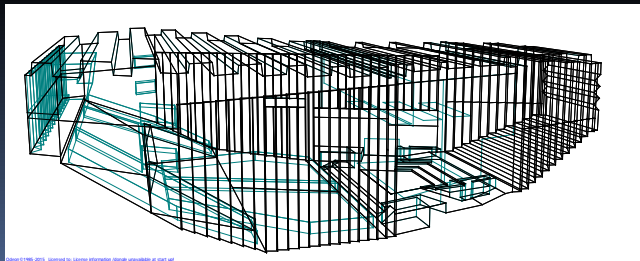
GS (stage) and GP (pit)



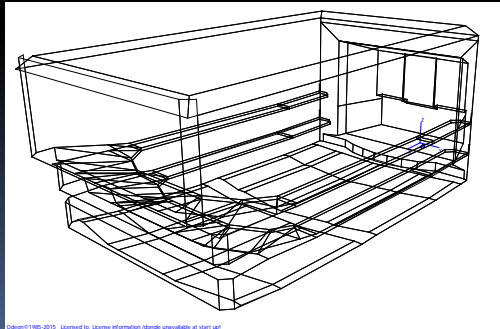
PG (rehearsal studio)



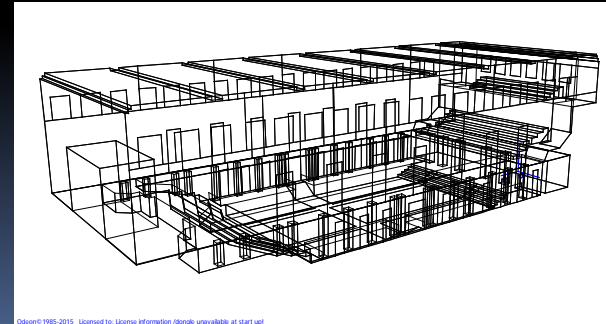
AC



OKH1 and OKH2



BSH



VM

Simulated metrics in 8 models

8 metrics, results from simulations in the 8 venue models. "X" = Optimum values.

Venue	$G_r - G_d$ [dB]	G_r [dB]	T_{30} [s]	G_{late} [dB]	ST_{late} [dB]	G [dB]	ST_{early} [dB]	G_d [dB]
GS	1	8	1,7	2	-18	11	-15	7
GP	5	10	1,0	-4	-25	12	-14	5
PG	6	13	1,4	9	-13	14	-12	7
AC	-2	5	2,1	1	-20	9	-19	6
VM	0	7	2,0	2	-18	10	-12	7
OKH 1	-3	4	1,5	0	-21	9	-16	7
OKH 2	-3	3	1,6	0	-21	9	-18	7
BS	-1	5	2,2	0	-22	9	-19	6
X	0	7	2,2	2	-19	10	-20	6

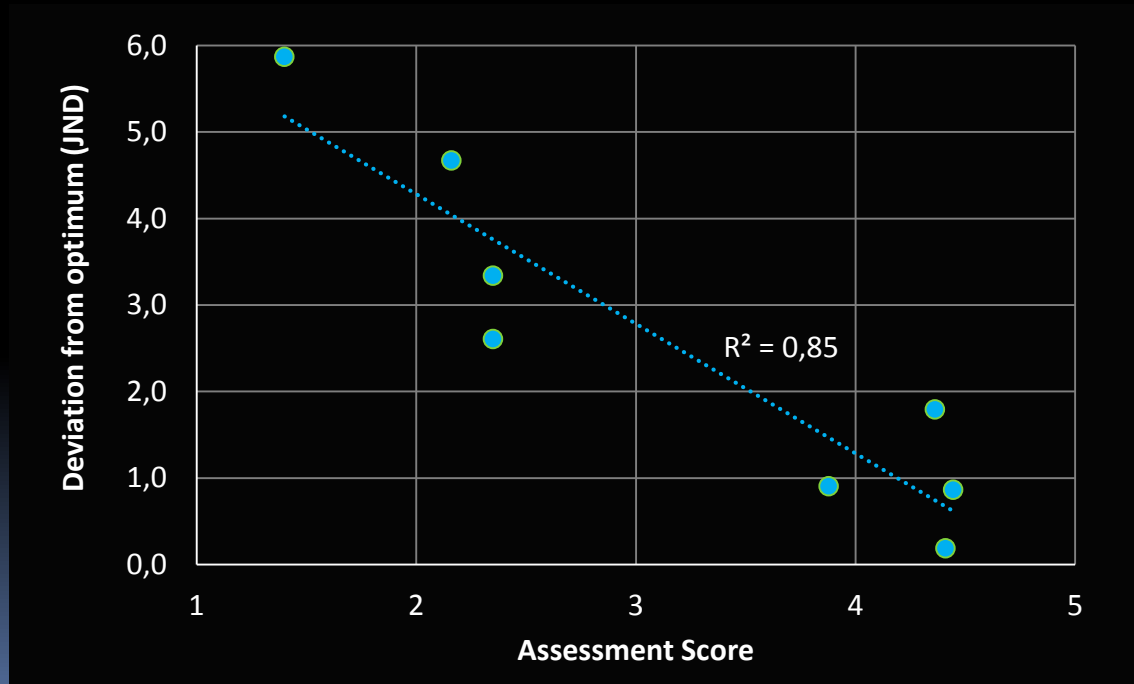
Deviations from Optimum, vs Score

8 metrics, their absolute deviations (JND) from Optimum, and correlation r and r^2 between deviations and Score, in 8 venues.

Venue	$G_d - G_r$ [JND]	G_r [JND]	T_{30} [JND]	G_{late} [JND]	ST_{late} [JND]	G [JND]	ST_{early} [JND]	G_d [JND]	Score
GS	1	1	4	0	1	1	5	1	3,9
GP	5	3	11	6	6	2	6	1	2,2
PG	6	6	7	7	6	4	8	1	1,4
AC	2	2	1	1	1	1	1	0	4,4
VM	0	0	2	0	1	0	8	1	4,4
OKH 1	3	3	6	2	2	1	5	1	2,3
OKH 2	3	3	5	2	2	1	2	1	2,3
BSH	1	1	0	2	3	1	1	0	4,4
r^2	0,85	0,74	0,71	0,64	0,51	0,49	0,22	0,09	1.0
r	-0,92	-0,86	-0,84	-0,8	-0,71	-0,7	-0,47	-0,29	-1.0

$|G_d - G_r|$ vs Score, 8 venues

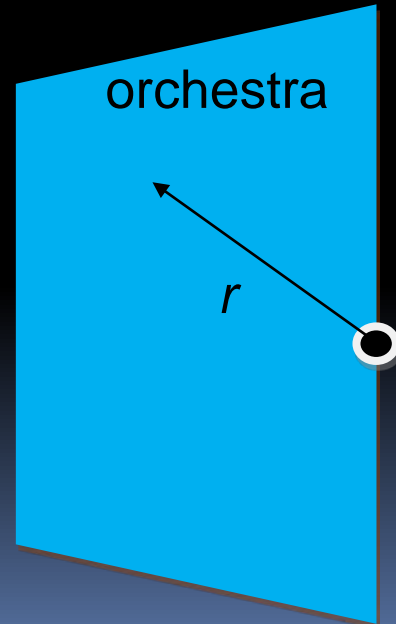
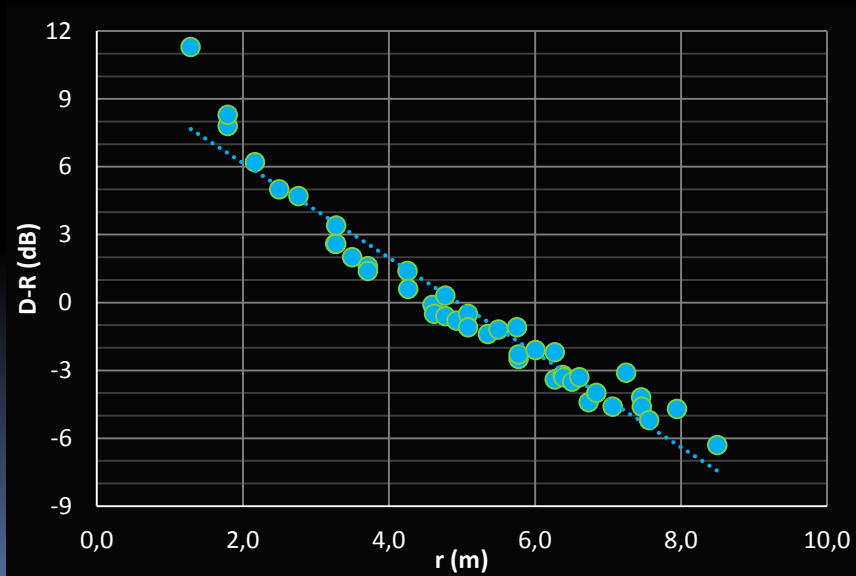
Absolute deviations (in JND) from Optimum, correlation $r^2=0.85$



$D-R$ (dB) vs distance r (m)

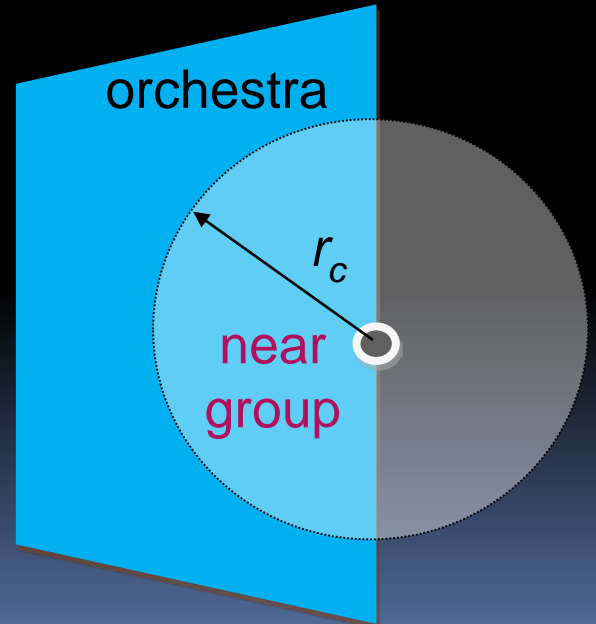
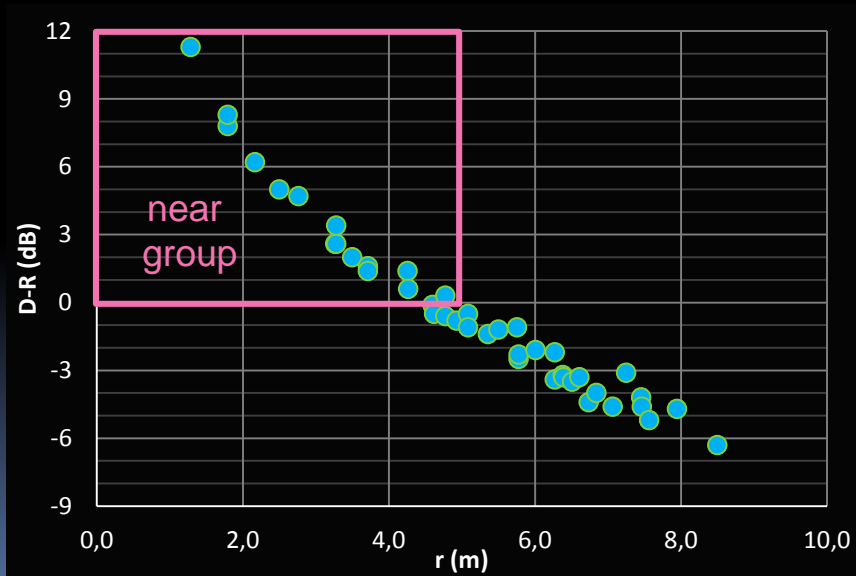
Mid-frequency average (500 and 1000 Hz octaves)

Trend line $D-R = 10\text{dB} - 2 * r$ (dB)



$D-R=0$, critical radius, near – far

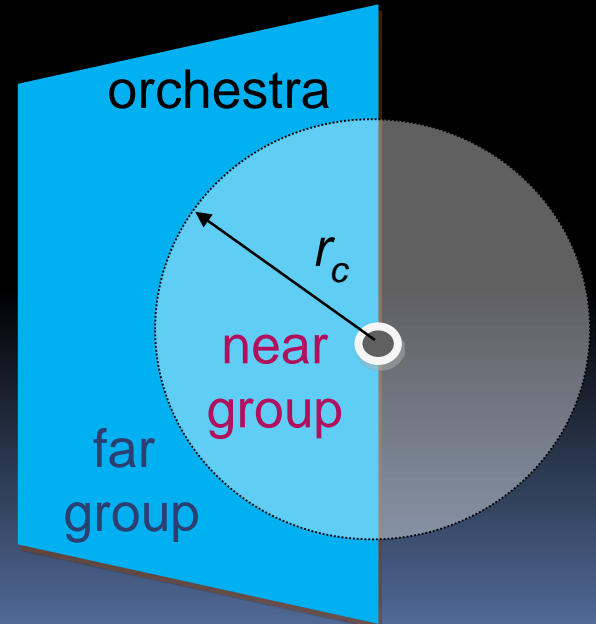
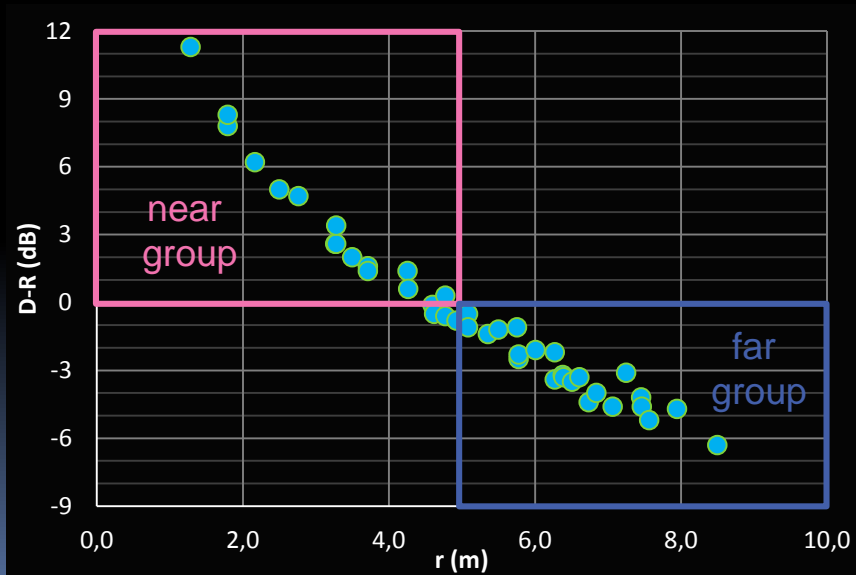
Near group heard via Direct Sound



$D-R=0$, critical radius, near – far

Near group heard via Direct Sound

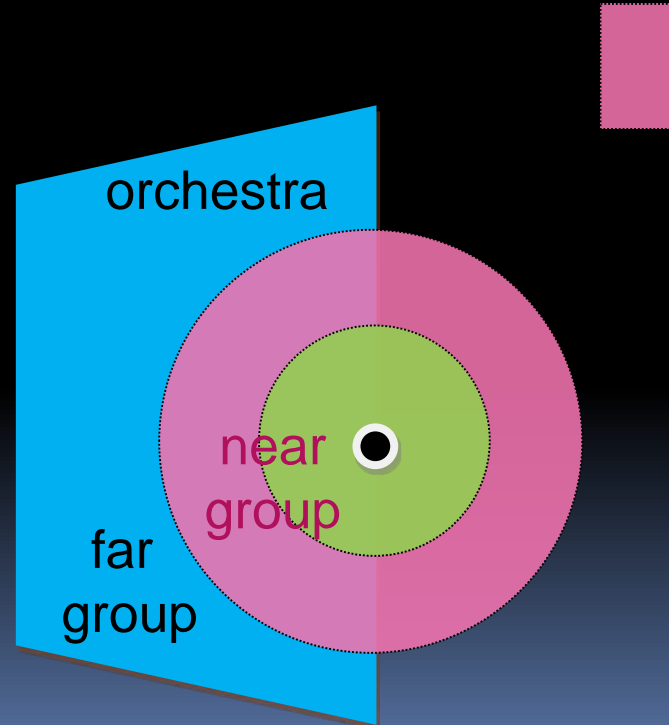
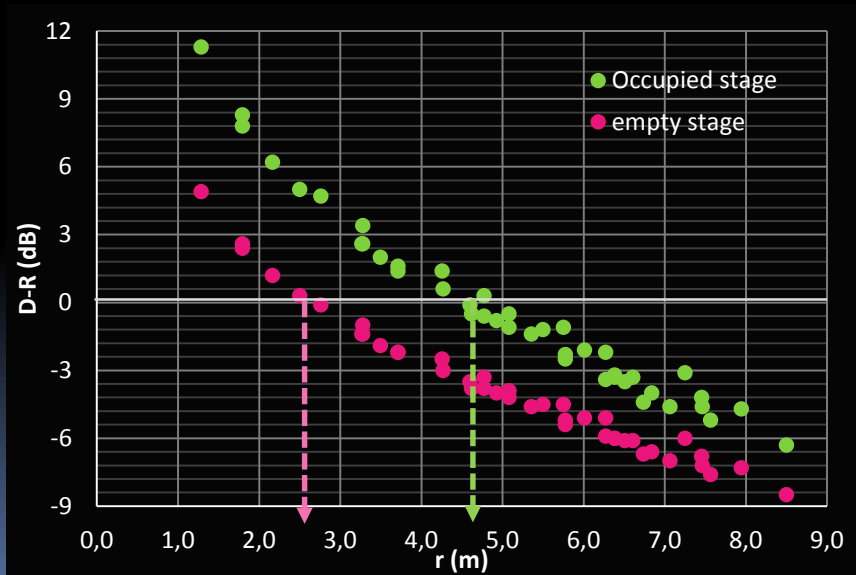
Far group heard via Reverberant Sound



Occupied stage vs Empty stage

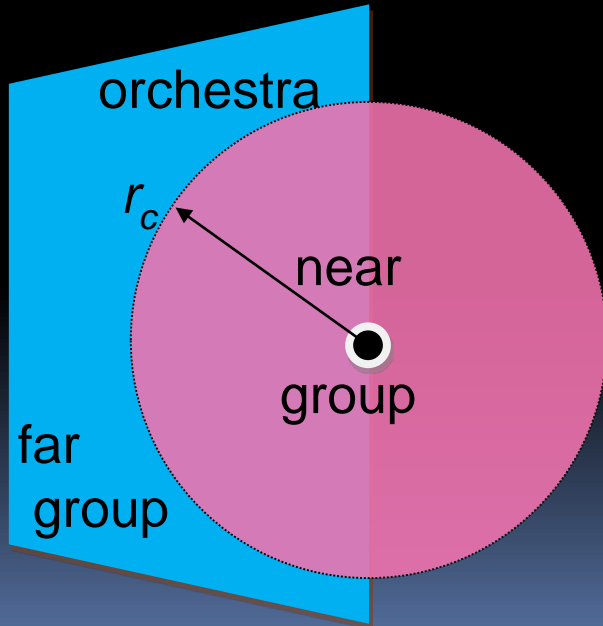
Critical Radius \approx 4.6 m with orchestra present

Critical Radius \approx 2.5 m on empty stage

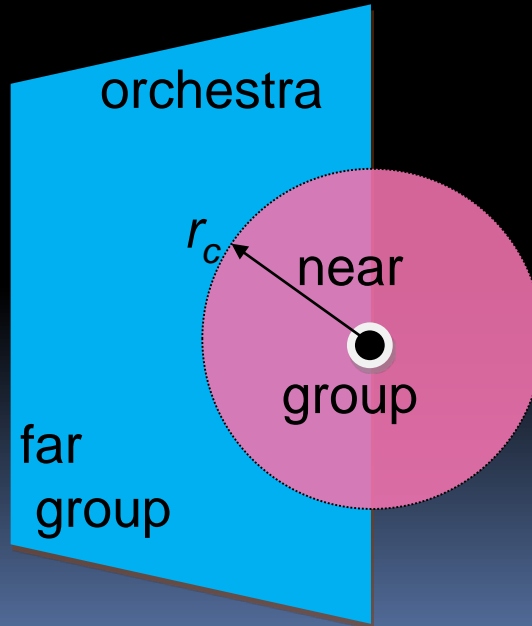


Significance of reverberant level G_r

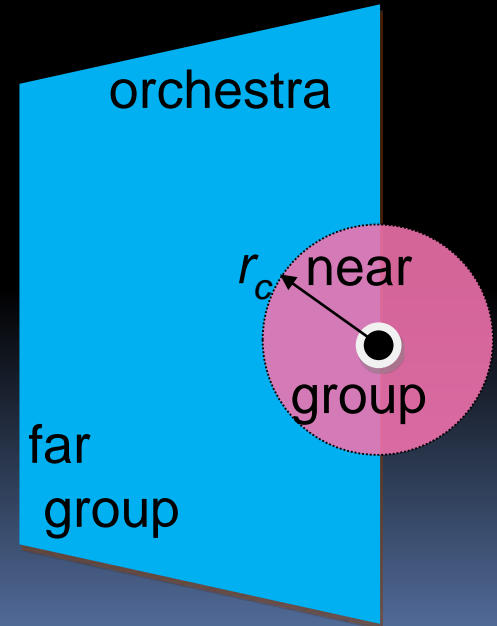
$G_r = 4\text{dB}$



$G_r = 7\text{dB}$



$G_r = 10\text{dB}$

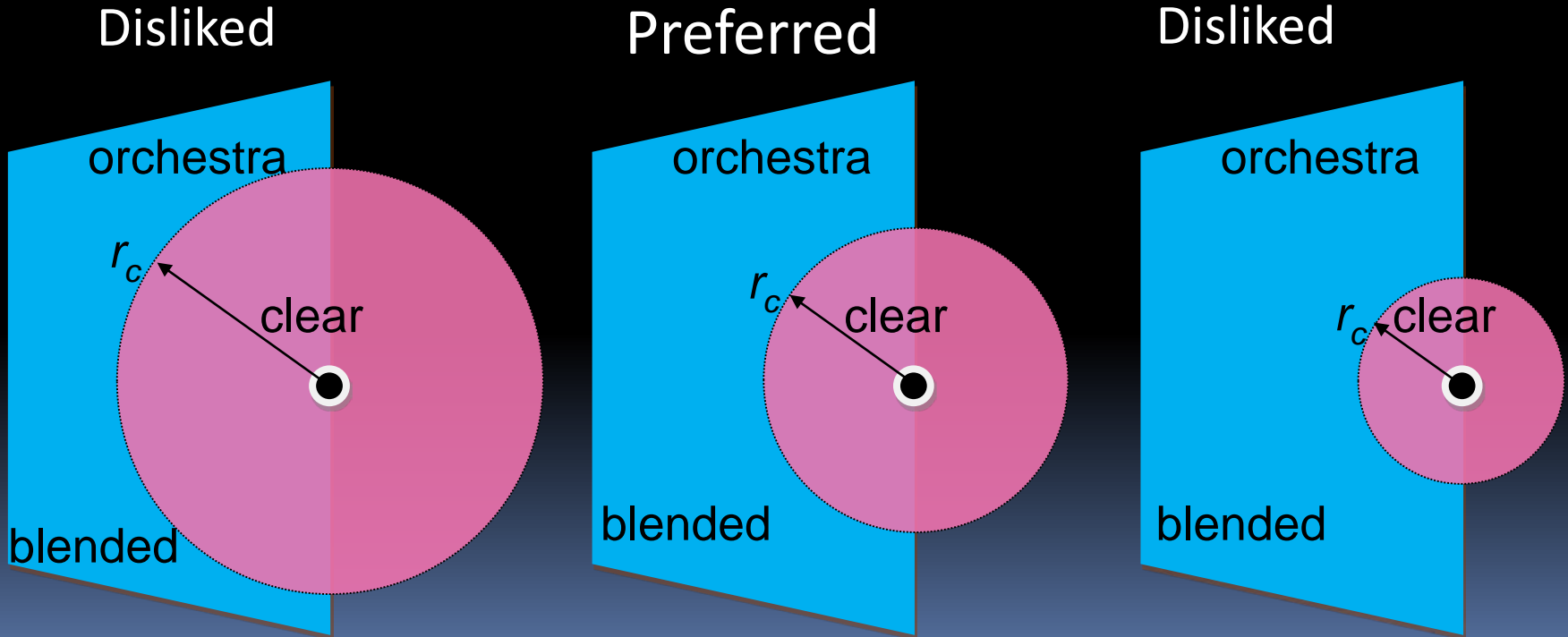


Analogy: Visibility range



Light	↔ Sound
Vision	↔ Hearing
Mist, Fog, Haze	↔ Reflected sound
Visibility Range	↔ Critical Radius
Misty	↔ Blended
Clear	↔ Clear
Diffuse	↔ Diffuse
Discern	↔ Discern
Transparent	↔ Transparent

This orchestra's preferred balance



Recommendation

- In terms of inter-orchestral D-R as discussed
 - Too low or too high D-R values
 - => escalating loudness and sound level exposure
 - => worsened conditions for inter-orchestral hearing
- Preliminary recommendation
 - simulate D-R over the orchestra in a 3D model
 - source in the position of Conductor/Concertmaster
 - Recommendation: D-R \approx 0 dB



Thank you

More info?

The www center for search, research and open sources in acoustics

www.akutek.info

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