

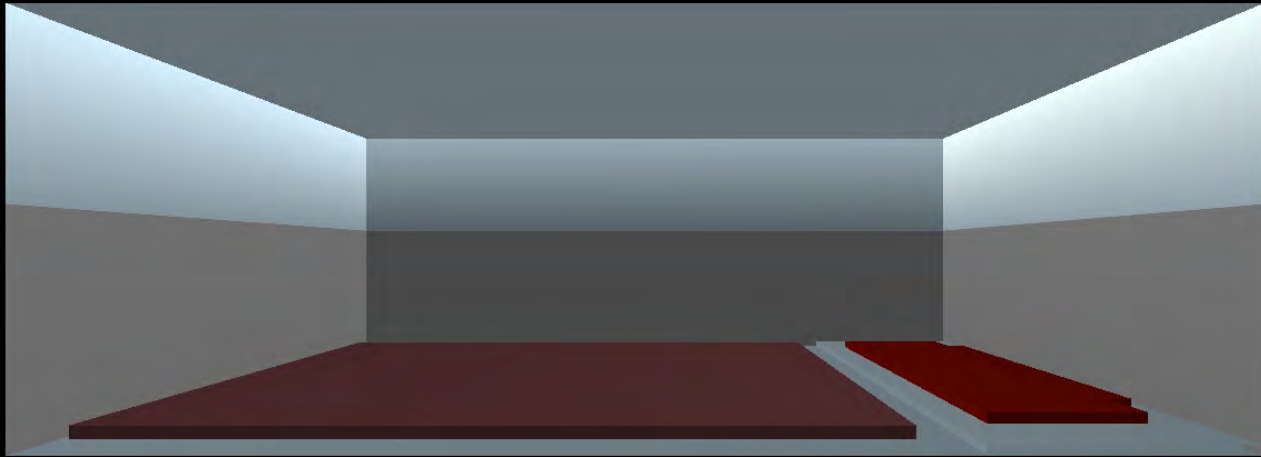
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Music Room Acoustics

REHEARSAL ROOM ACOUSTICS FOR THE ORCHESTRA MUSICIAN

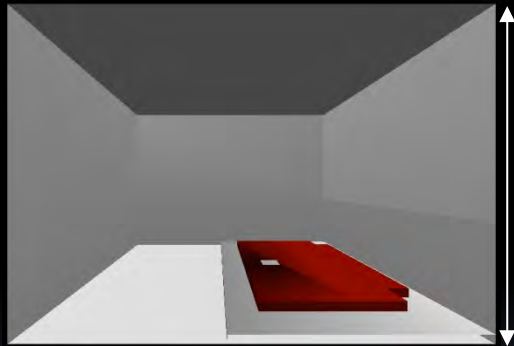
Intro

- What are the proper acoustics of a good rehearsal room for orchestra musicians?
- T equal to performance space? -> too LOUD
- G equal to performance space? -> too DRY
- Suggested common features in spaces for Rehearsal and Performance
 - Foreground (own instrument) controlled by musician
 - Background (others and reverb sound) varies
 - Foreground-to-Background Balance (FBB) is assumed to be critical for intonation and timing
 - If FBB varies from situation to situation,
 - Would musician play consistently (unaffected by FBB)?
 - Would musician have to adjust power to restore FBB?
 - Is FBB consistent throughout good rooms?



4 models

Concert Hall,
height=18m



Rehearsal Studio,
height=14m



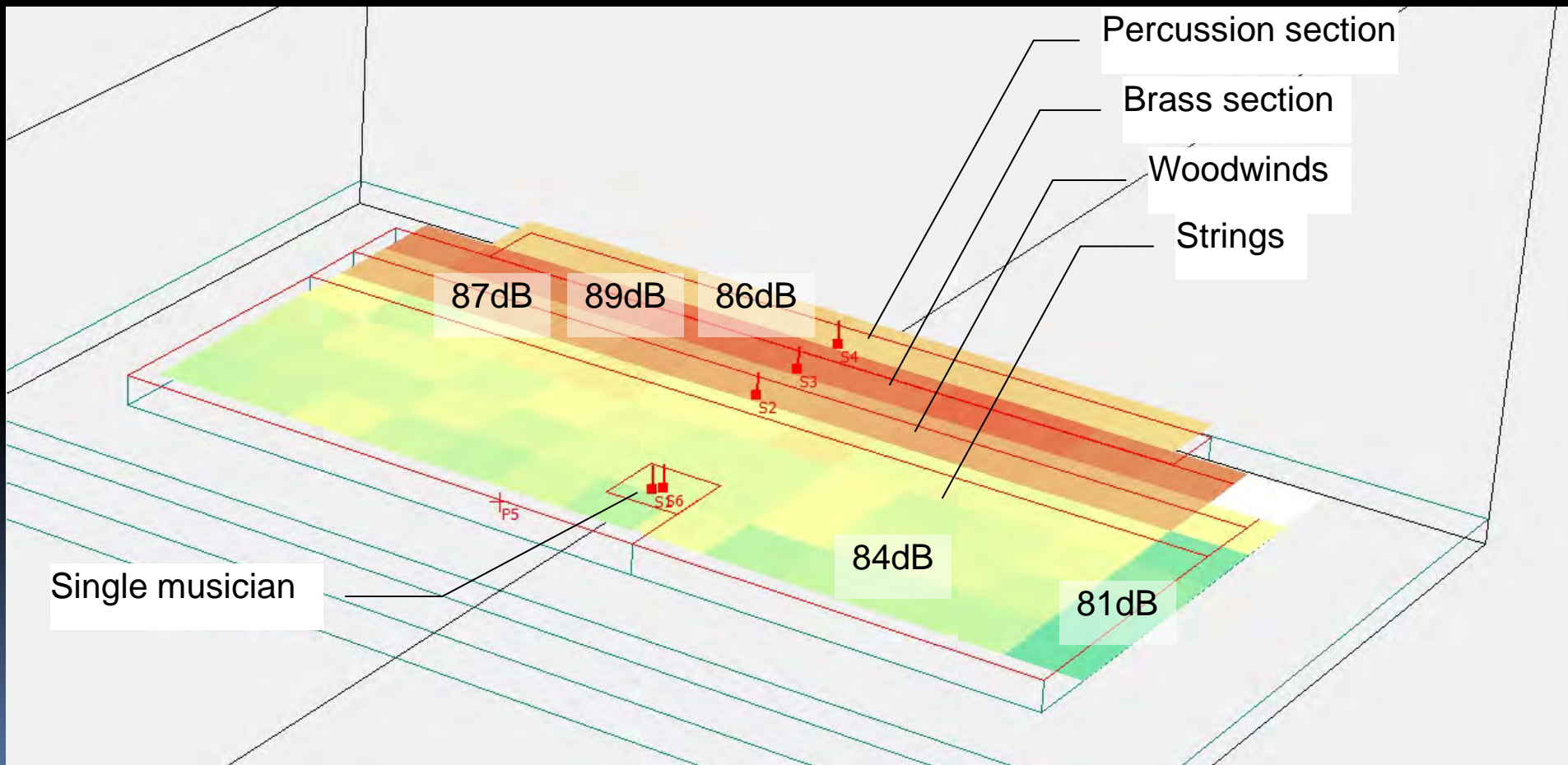
Group rehearsal room
height=5.0m



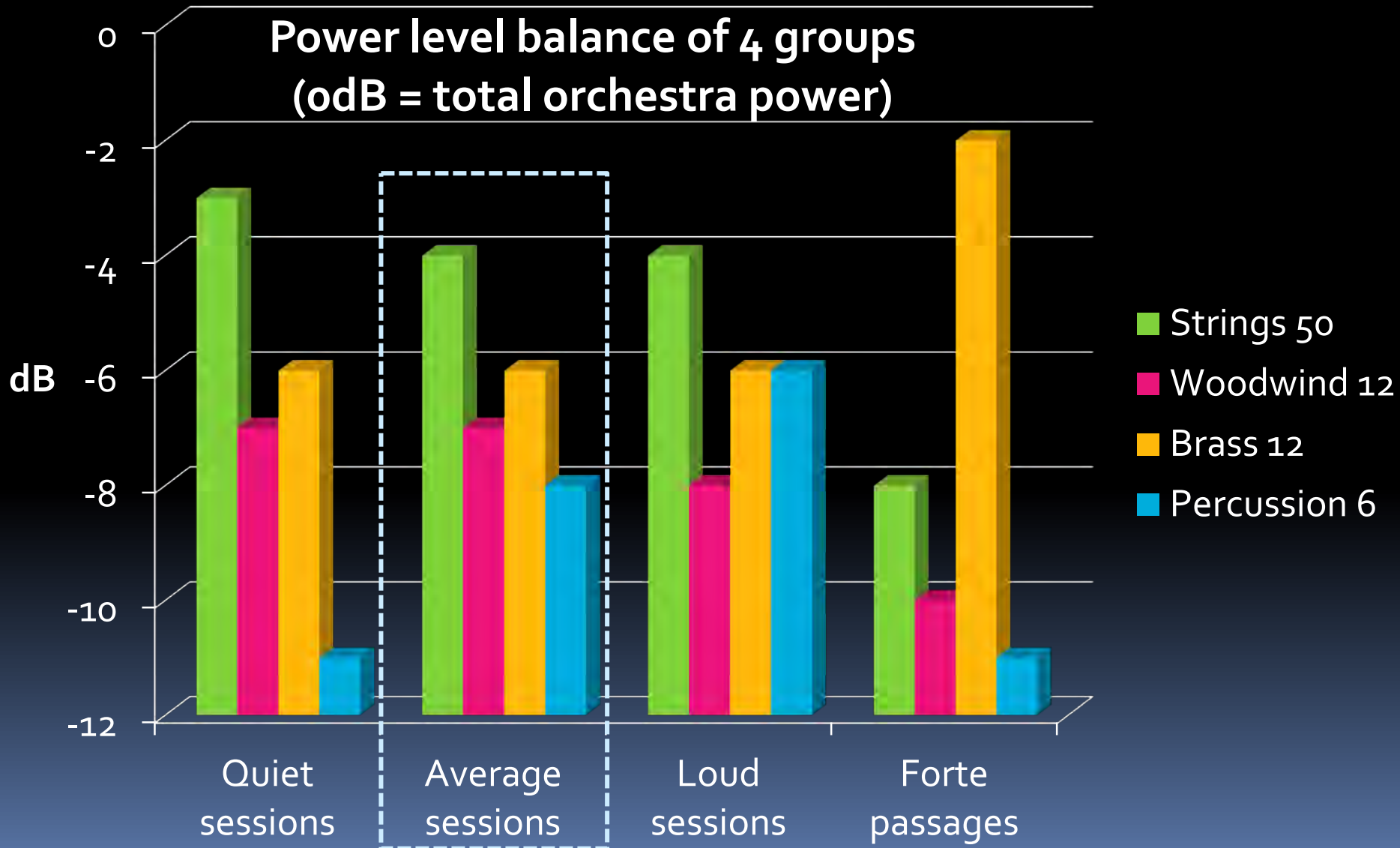
Individual rehearsal room
height=2.5-2.7m

Source power best fit to measurements (Queensland)

1609 measurements, all orchestra sessions 2004-2007 (O'Brien et al 2008)



Orchestra Power Balance



$V-T-G_{\text{ref}1}$ satisfying NS8178

Room and use	Musicians #	Volume V m^3	Reverb time T s	Reverb Gain $G_{\text{ref}1}$ dB
Small rehearsal room individual practice	1	40	0.4	25
Medium size rehearsal room group rehearsals, e.g. 1 st violin	15	700	0.8	18
Large rehearsal room full orchestra rehearsals	80	5600	1.1	8
Concert hall	80	18000	2.1	5

Results, all 18 rooms (paper)

Room type Room ID	CONCERT HALL			REHEARSAL STUDIO					GROUP REHEARSAL			INDIVIDUAL REHEARSAL ROOMS						
	CH	CHb	CHc	RHa	RHb	RHc	RHd	RHe	g15c	g15d	g15e	i2a	i2c	i2d	i2e	i8178	i8178LE	i8178DE
L	50	50	50	20	20	20	20	20	14	14	14	2,9	2,9	2,9	2,9	3	3	3
B	20	20	20	20	20	20	20	20	9,6	9,6	9,6	3,8	3,8	3,8	3,8	5	5	5
H	18	18	18	14	14	14	14	14	5	5	5	2,5	2,5	2,5	2,5	2,7	2,7	2,7
N	80	80	80	80	80	80	80	80	15	15	15	1	1	1	1	1	1	1
V	18000	18000	17800	5600	5600	5600	5600	5600	691	691	691	28	28	28	28	41	41	41
T30 KM (occ)	2,1	1,6	2,2	1,3	1,1	1,2	1,1	2,3	0,9	1,6	0,8	0,2	0,4	0,4	0,5	0,4	0,7	0,7
T30 glob (occ)	2,2	1,5	2,2	-	-	1,3	1,1	2,4	0,9	1,5	0,6	-	0,4	0,4	0,5	0,4	0,7	0,7
T30 glob (unoccupied)	2,5	1,3	2,7	-	-	1,8	1,4	3,7	1,3	2,7	0,6	-	-	-	-	-	-	-
dryself	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,0
dryothers	77,4	77,4	77,4	77,4	77,4	77,4	77,4	77,4	76,5	76,5	76,5	-	-	-	-	-	-	-
dry all	83,3	83,3	83,3	83,3	83,3	83,3	83,3	83,3	83,1	83,1	83,1	82,0	82,0	82,0	82,0	82,0	82,0	82,0
LAeq (others)	80,0	79,5	79,8	80,5	79,4	79,9	79,8	82,2	79,8	81,8	77,3	-	-	-	-	-	-	-
LAeq (self)	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,1	82,2	82,0	82,4	82,7	83,2	83,5	83,0	83,8	83,2
LAeq (all)	84,1	83,9	84,1	84,4	83,9	84,1	84,1	85,1	84,1	85,0	83,3	82,4	82,7	83,2	83,5	83,0	83,8	83,2
reverberant level all	76,3	75,0	76,3	77,9	75,0	76,3	76,3	80,4	77,2	80,5	69,8	71,8	74,4	77,0	78,1	76,1	79,1	77,0
reverberant level, others	76,5	75,3	76,0	77,5	75,0	76,3	76,0	80,4	77,0	80,2	69,5	-	-	-	-	-	-	-
reverberant level, self	-	-	-	-	-	-	-	-	65,6	68,7	-	71,8	74,4	77,0	78,1	76,1	79,1	77,0
FG	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,0	82,0
BG	79,9	79,3	79,9	80,6	79,3	79,9	79,9	82,1	79,9	81,9	77,3	71,8	74,4	77,0	78,1	76,1	79,1	77,0
FG-BG	2,0	2,5	2,2	1,5	2,6	2,1	2,2	-0,2	2,2	0,2	4,7	10,2	7,6	5,0	3,8	5,9	2,9	5,0
NS8178 T30(V) highlimit	-	-	-	1,8	1,8	1,8	1,8	1,8	1,2	1,2	1,2	0,4	0,4	0,4	0,4	0,5	0,5	0,5
NS8178 T30(V) lowlimit	-	-	-	1,2	1,2	1,2	1,2	1,2	0,8	0,8	0,8	0,3	0,3	0,3	0,3	0,3	0,3	0,3
NS8178 medium T30	2,0	2,0	2,0	1,5	1,5	1,5	1,5	1,5	1,0	1,0	1,0	0,3	0,3	0,3	0,3	0,4	0,4	0,4
10lg(T.NS) KM	0,2	-1,0	0,4	-0,5	-1,2	-0,9	-1,2	2,0	-0,5	2,0	-1,0	-2,1	1,0	1,0	1,9	0,0	2,4	2,4
ST early (unocc)	-20	-21	-18			-19	-18	-16	-7	-6	-14					-1		
ST late (unocc)	-14	-17	-16			-14	-16	-9	-8	-3	-21					-11		
ST total (unocc)	-13	-15	-14			-13	-14	-8	-5	-1	-13					-1		
T30 (unocc)	2,5	1,3	2,7			1,8	1,4	3,7	1,3	2,7	0,6					0,5		
Stbal	-6	-4	-2			-5	-2	-7	0	-3	7					9		
Sttot+10lgN	5	2	3			5	3	10	4	9	-9					-11		
Sttot+10lgN	6	4	5			6	5	11	7	11	-1					-1		
T, all	2,2	1,5	2,2	1,4	1,4	1,4	1,1	2,3	0,9	1,5	0,6							
T, others	2,3	1,5	2,3	1,5	1,6	1,6	1,1	2,3	0,9	1,5	0,6							
G, all	3,1	2,9	3,1	3,4	2,9	3,1	3,1	4,1	3,1	4	2,3							
G, others	-1	-1,5	-1,2	-0,5	-1,6	-1,1	-1,2	1,2	-1,2	0,8	-3,7							
EDT, all	1,5	1,2	1,3	1,5	1	1,5	1,3	2,2	0,6	1,3	0							
EDT, others	1,6	1,3	2,1	1,3	1,3	1,3	1,2	2,3	0,9	1,4	0,3							
C, all	8,2	10	8,8	6,4	8,9	7,7	8,4	3,7	10,9	6,6	22,2							
C, others	2,9	4,7	3,7	1	3,2	2,2	3	-1,5	6,3	2,6	16,5							

Results, level components at violinist's ears, 13 rooms

Room type	CONCERT HALL			REHEARSAL STUDIO			GROUP REHEARSAL			INDIVIDUAL REHEARSAL ROOMS				
	OK	-	OK	x	x	-	x	-	-	x	x	-	x	
V	18000			5600			691			28				41
T30 glob (occ)	2,2	1,5	2,2	1,3	1,1	2,4	0,9	1,5	0,6	0,4	0,4	0,5	0,4	
G refl theor. r->0	6	4	8	9	8	11	16	18	14	26	26	28	25	
LAeq (all)	84	84	84	84	84	85	84	85	83	83	83	83	83	
LAeq (self)	82	82	82	82	82	82	82	82	82	83	83	83	83	
LAeq (others)	80	79	80	80	80	82	80	82	77	-	-	-	-	
dry all	83	83	83	83	83	83	83	83	83	82	82	82	82	
dryself	82	82	82	82	82	82	82	82	82	82	82	82	82	
dryothers	77	77	77	77	77	77	76	76	76	-	-	-	-	
Reverb LAeq all	76	75	76	76	76	80	77	80	70	74	77	78	76	
Reverb LAeq self	-	-	-	-	-	-	66	69	58	74	77	78	76	

Results, level balance parameters

Room type	CONCERT HALL			REHEARSAL STUDIO			GROUP REHEARSAL			INDIVIDUAL REHEARSAL ROOMS			
Recommended (NS8178=X)	Yes	-	Yes	x	x	-	x	-	-	-	-	-	x
V	18000			5600			691			28			41
T30 glob (occ)	2,2	1,5	2,2	1,3	1,1	2,4	0,9	1,5	0,6	0,4	0,4	0,5	0,4
G refl theor. r->0	6	4	8	9	8	11	16	18	14	26	26	28	25
FG-BG	2	3	2	2	2	0	2	0	5	8	5	4	6
Dry-Reverb, all	7	8	7	7	7	3	6	3	13	8	5	4	6
Dry-Reverb, self	-	-	-	-	-	-	16	13	24	8	5	4	6

Highlighted: Consistent values of good rooms, FG-BG=2dB

Room type	CONCERT HALL			REHEARSAL STUDIO			GROUP REHEARSAL			INDIVIDUAL REHEARSAL ROOMS			
	Yes	-	Yes	X	X	-	X	-	-	-	-	-	X
V	18000			5600			691			28			41
T30 glob (occ)	2,2	1,5	2,2	1,3	1,1	2,4	0,9	1,5	0,6	0,4	0,4	0,5	0,4
G refl theor. r->0	6	4	8	9	8	11	16	18	14	26	26	28	25
FG-BG	2	3	2	2	2	0	2	0	5	8	5	4	6
Dry-Reverb, all	7	8	7	7	7	3	6	3	13	8	5	4	6
Dry-Reverb, self	-	-	-	-	-	-	16	13	24	8	5	4	6

Foreground = dry sound of own instrument

Background= dry sound from other instruments + all reverberant sound

Foreground-Background-Balance appears relevant for ensemble but not for individual practice

Highlighted: Consistent values of good rooms Dry-Reverb=6-7dB

Room type	CONCERT HALL			REHEARSAL STUDIO			GROUP REHEARSAL			INDIVIDUAL REHEARSAL ROOMS			
Recommended (NS8178=X)	Yes	-	Yes	X	X	-	X	-	-	-	-	-	X
V	18000			5600			691			28			41
T30 glob (occ)	2,2	1,5	2,2	1,3	1,1	2,4	0,9	1,5	0,6	0,4	0,4	0,5	0,4
G refl theor. r->0	6	4	8	9	8	11	16	18	14	26	26	28	25
FG-BG	2	3	2	2	2	0	2	0	5	8	5	4	6
Dry-Reverb, all	7	8	7	7	7	3	6	3	13	8	5	4	6
Dry-Reverb, self	-	-	-	-	-	-	16	13	24	8	5	4	6

Highlighted: Consistent values of good rooms Dry-Reverb=6-7dB

Room type	CONCERT HALL			REHEARSAL STUDIO			GROUP REHEARSAL			INDIVIDUAL REHEARSAL ROOMS				
	Yes	-	Yes	X	X	-	X	-	-	-	-	-	X	
V	18000			5600			691			28				41
T30 glob (occ)	2,2	1,5	2,2	1,3	1,1	2,4	0,9	1,5	0,6	0,4	0,4	0,5	0,4	
G refl theor. r->0	6	4	8	9	8	11	16	18	14	26	26	28	25	
FG-BG	2	3	2	2	2	0	2	0	5	8	5	4	6	
Dry-Reverb, all	7	8	7	7	7	3	6	3	13	8	5	4	6	
Dry-Reverb, self	-	-	-	-	-	-	16	13	24	8	5	4	6	

Consistent Dry-Reverb balance
is equivalent to

Consistent ratio between ensemble distances and Critical Distance

Not always the-bigger-the-better for individual practice

Room type	CONCERT HALL			REHEARSAL STUDIO			GROUP REHEARSAL			INDIVIDUAL REHEARSAL ROOMS			
	Yes	-	Yes	x	x	-	x	-	-	-	-	-	x
V	18000			5600			691			28			41
T30 glob (occ)	2,2	1,5	2,2	1,3	1,1	2,4	0,9	1,5	0,6	0,4	0,4	0,5	0,4
G refl theor. r->0	6	4	8	9	8	11	16	18	14	26	26	28	25
FG-BG	2	3	2	2	2	0	2	0	5	8	5	4	6
Dry-Reverb, all	7	8	7	7	7	3	6	3	13	8	5	4	6
Dry-Reverb, self	-	-	-	-	-	-	16	13	24	8	5	4	6

Dry-Reverb balance may explain why a bigger 1.5 s rehearsal space may not be preferred for individual practice by the orchestra musician

Optimizing between too high FBB and too low FBB

- FBB too low:
 - Own instrument masked – hard to intonate
 - Sound image over-saturated
 - Hard to discriminate details (conductor aspect)
 - Long term effect: Forced playing style, others do the same, more spectral masking, vicious circle
- FBB too high:
 - Orchestra sound too weak for own intonation and timing (Background too weak)
 - Lack of source broadening and «chorus effect» (individual and group)
 - More....

Conclusions

- Odeon models with source power matching 1600+ measurements (Queensland 2004-2007)
 - Big concert hall
 - Rehearsal studio
 - Group rehearsal room
 - Individual rehearsal room
- Results: It's all about LEVEL BALANCE in musician's sound image, RT becomes significant only in subselections where level balance is proper
 - Foreground-Background-Balance FBB is 2dB consistently in good ensemble rooms
 - Dry-Reverberant-Balance DRB is 6-7dB consistently in all good rooms, including individual use
- Too much or too little FBB affects intonation and timing, and FBB is affected by Reverb Level
- Reverberant sound has little direct effect on the sound pressure levels at the musician's ear
 - however, it can drive the musician to play louder by increasing the background
- Smaller rooms with shorter RT may be preferred for individual rehearsal, due to more «source enlargement», higher reflection density and higher reverb level compensating for missing ensemble

Further work

- Extend to other instruments and groups
- Spectral significance
 - dynamic instrument spectrum meets room response spectrum (see discussion in paper)
- Measurements on musician's ear
- Further investigations into consistent parameters
 - Foreground-Background Balance
 - Dry-Reverb Balance
 - Critical distance related to inter-orchestral distance

Forum Acusticum 2014 Krakow teaser: Measurements in musician's ears



Small rehearsal room $T=0.4$



Big rehearsal room $T=0.7$



Orchestra Rehearsal Studio $T=1.0$



Orchestra Pit Opera House $T=2.1$

Thank you

More info?

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

www.akutek.info

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