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Rehearsal Room Acoustics
Ensemble conditions

Restrictions on V-T combinations related to ensemble size

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Key features related to A, V, T, and r

Reverberation Time (Sabine)	$T = 0.16*V/A$		[s]
Absorption (Sabine)	$A = 0.16*V/T$		[m2Sa]
Direct Sound Level	$Gd = 100/r^2$		[dB]
Reverb Level 1 (Barron)	$Gr = 10*lg(31200*T/V)$	$- 0.176*r/T$	[dB]
Reverb Level 2 (Barron)	$Gr = 37 - 10*lg(A)$	$- 0.176*r/T$	[dB]
Reverberation Distance (classical)	$RD = (A/16\pi)^{0.5}$		[m]
Direct-to-Reverberant Balance	$DR = Gd - Gr$		[dB]

Note! Absorption Area A alone controls Reverb Level and Reverb Distance

Gade (2012)

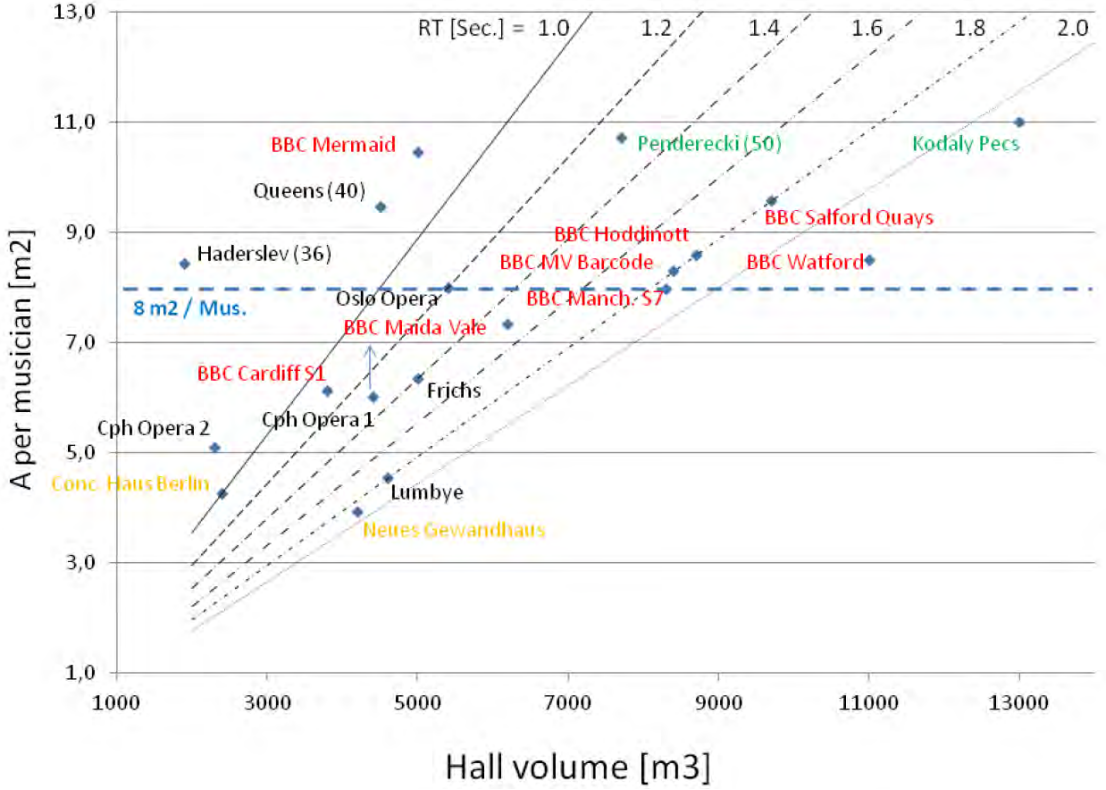
Absorption area A in ensembles with N musicians

Suggestion A>N*8 m2Sa

Equivalent: V/N > 50*T

Purpose: Control of Sound Exposure Levels

What other implications?



Implication (1) of A > N*8 ⇔ V/N > 50*T

Reverb sound level Gr < 28dB – 10*lg(N)

< 16 dB	for 16 musicians
< 14 dB	for 25 musicians
< 12 dB	for 40 musicians
< 10 dB	for 63 musicians
< 8 dB	for 100 musicians

Implication (2) of A > N*8 ⇔ V/N > 50*T

If an ensemble of N musicians occupy the floor surface S=1.5*N, then

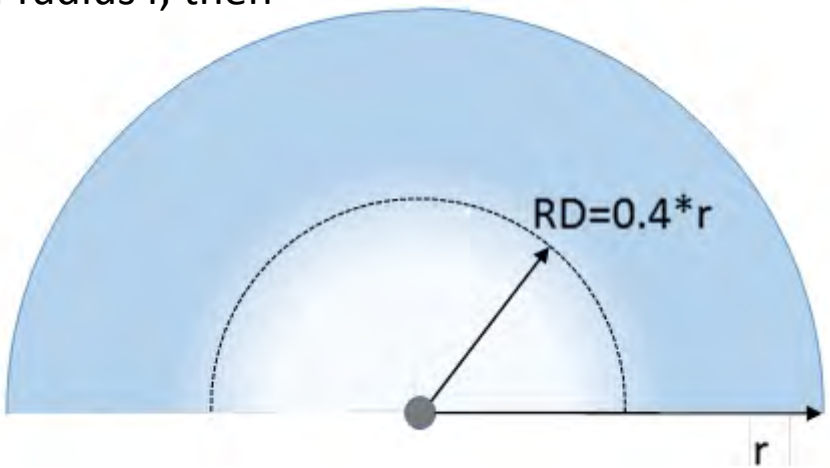
Reverberation distance $RD > 2.3*S^{0.5}$

If the ensemble is seated within a semi-circle of radius r, then

$RD > 0.4 * r$

At the dashed semi-circle with radius RD,

Direct-to-Reverb Balance is D-R=0 dB



Acoustical Transparency, e.g. at conductor's ears

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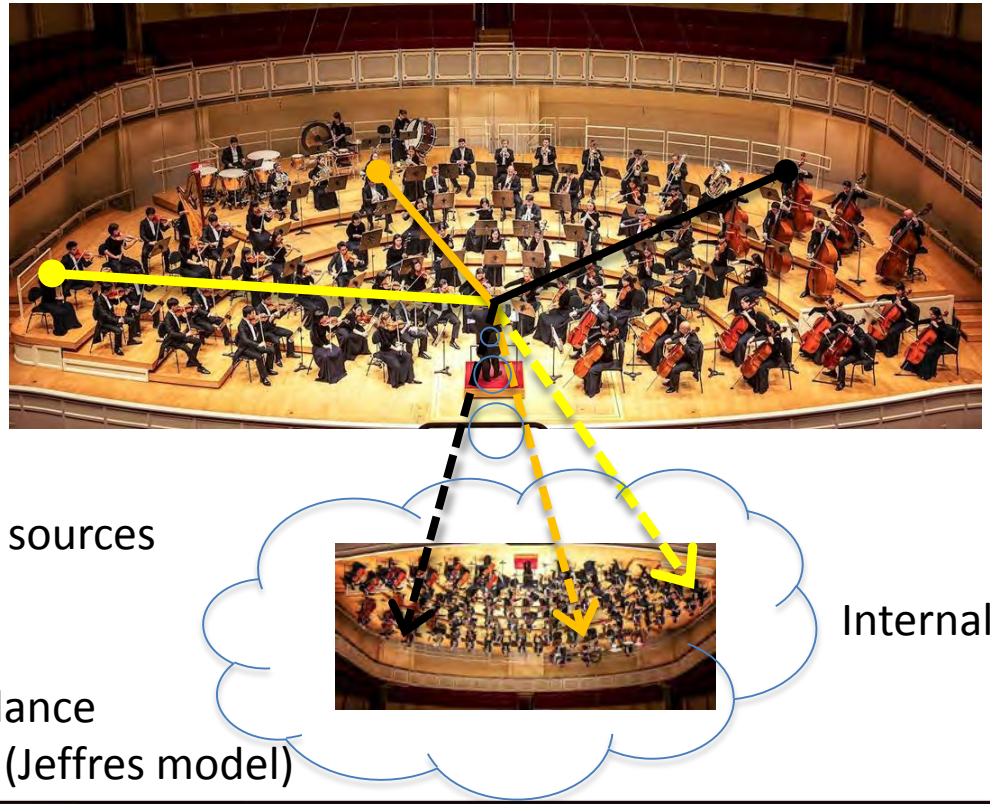
Complex sound image perception by mapping



External sources

Internal representation in brain

Discerning between sources depends on

- Direct Sound
- Sufficient D-R balance
- Binaural Hearing (Jeffres model)

Acoustical Transparency

Definition: Degree to which direct sound can be heard in the presence of reverb sound

Suggested metric is the Direct-to-Reverberant sound level D-R = Gd – Gr, the receiver being an ear position, and the source in the position of a musical instrument

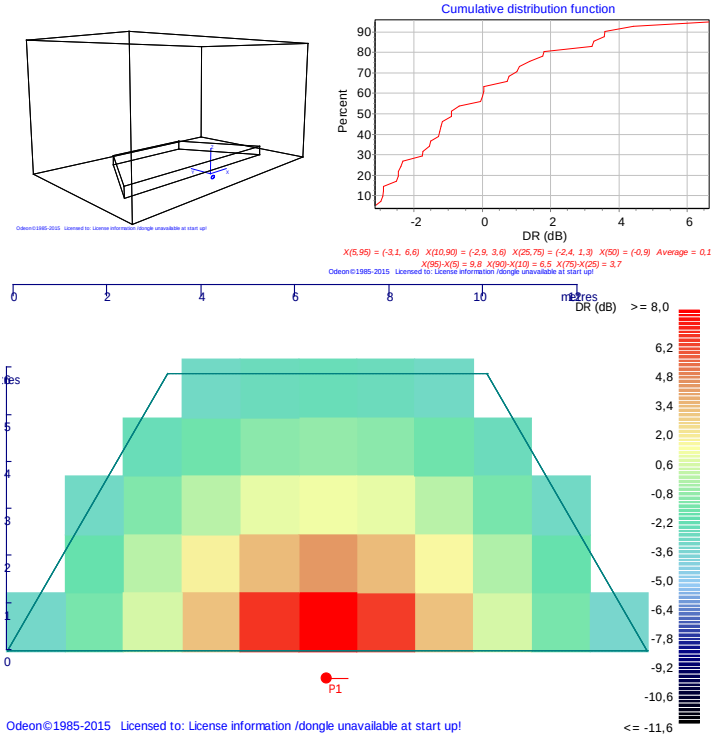
Suggested criterion for ensembles is D-R (average) = 0dB from musicians to conductor

Simulation experiments has shown that this average is a good estimate even for the average inter-orchestral D-R

A case study in Bergen 2012 concluded that a symphony orchestra
- judging 8 venues, simulated *average(D-R)* varied between *+3dB* and *-6dB*
- their preference peaked where *average(D-R)* ≈ *0dB*

(Skålevik, IOA, Hamburg, 2018 http://www.akutek.info/Papers/MS_Hamburg_IOA_2018.pdf)

Acoustical Transparency, ensemble simulations



Ensemble D-R, N=40

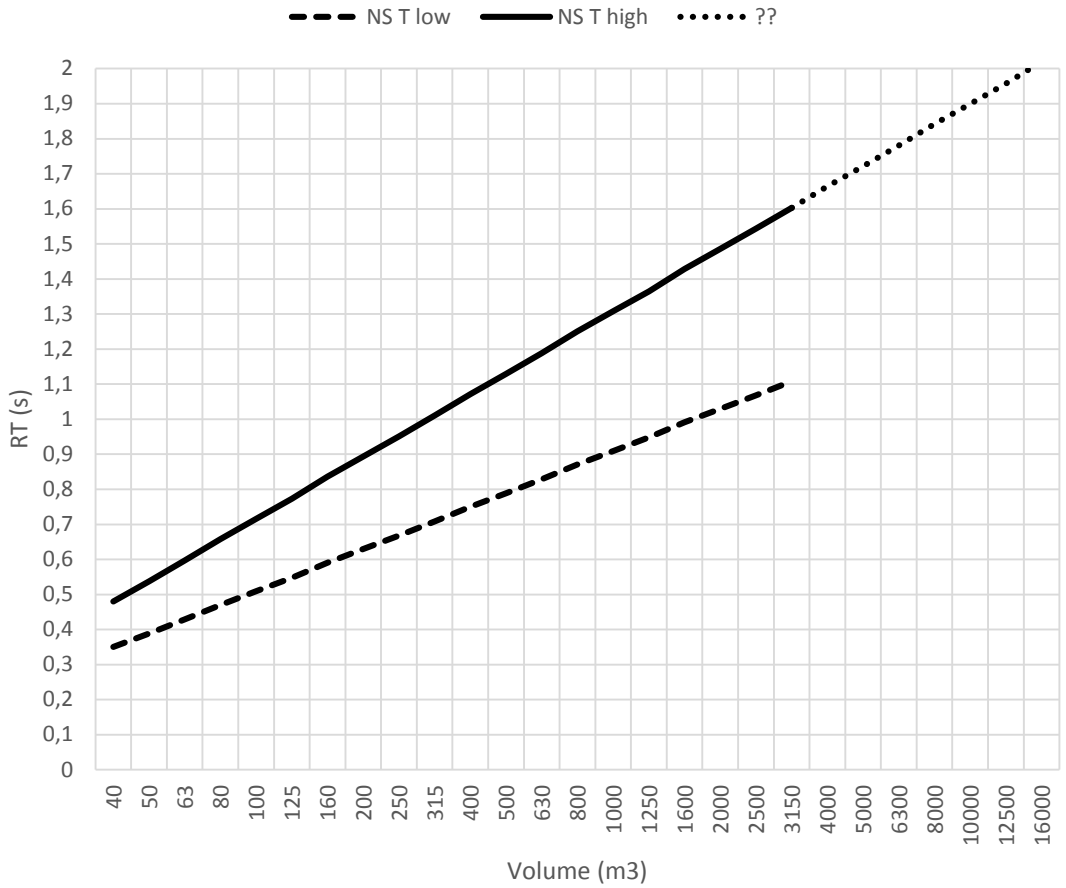
Simulations in Odeon 14, demanding D-R(avr) = 0dB

N	**16**	**25**	**40**	**63**	**100**
V	494	877	1625	2986	5607
T low(NS)	0,79	0,89	0,99	1,1	1,2
T high(NS)	1,1	1,3	1,4	1,6	1,8
T	0,54	0,66	0,81	1,0	1,2
T occ	0,44	0,53	0,66	0,81	0,99
Gr empty	15	13	12	10	7
Gr occ	11	10	8	6	4
D-R empty	-4	-4	-4	-4	-4
D-R occ	0	0	0	0	0
DR occ	3,1	3,8	4,7	6,9	8,7
A/N empt	**9**	**9**	**8**	**8**	**7**

NS-8178

Limits for T related to Volume,

For un-reinforced music



NS-8178

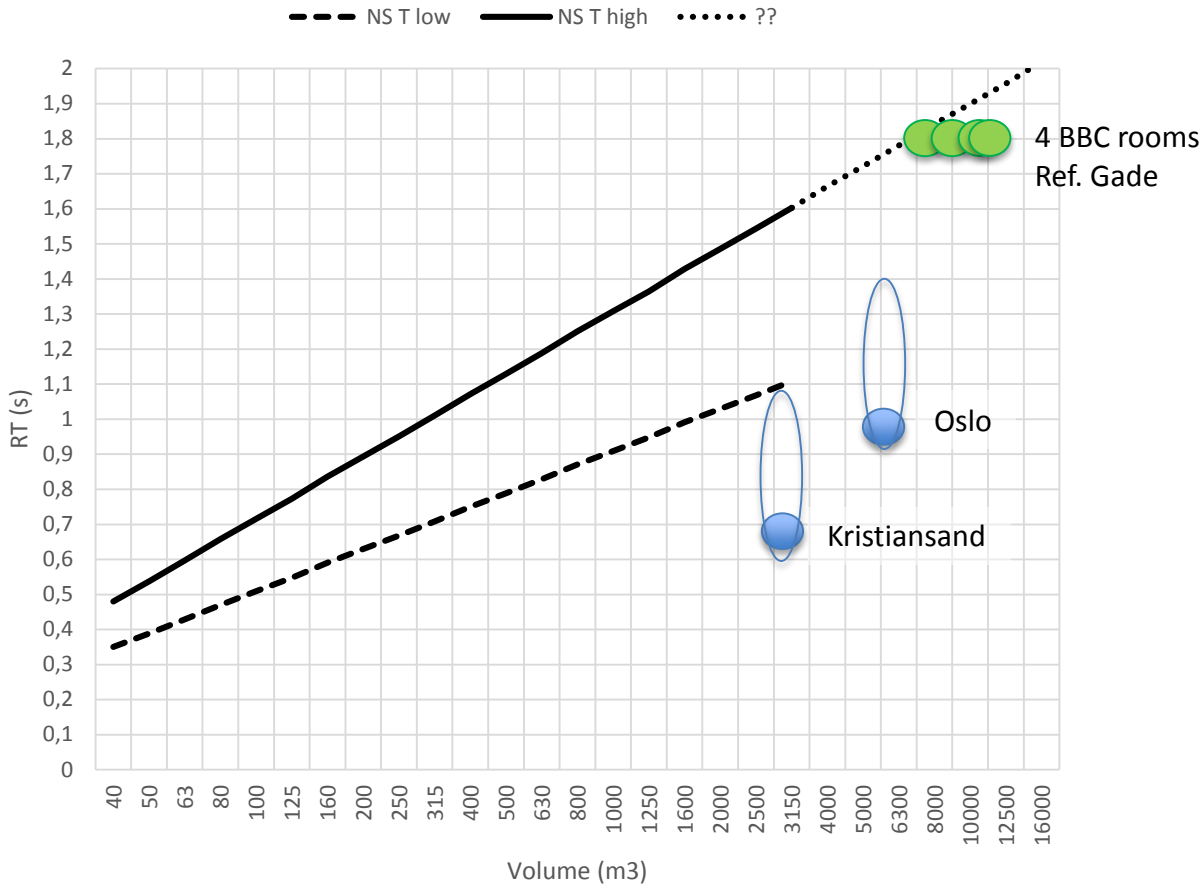
Limits for T related to Volume,
Un-reinforced music

Selected examples
Symphony Orchestras

= variable range

= preferred by musicians

= musicians satisfied



Summary

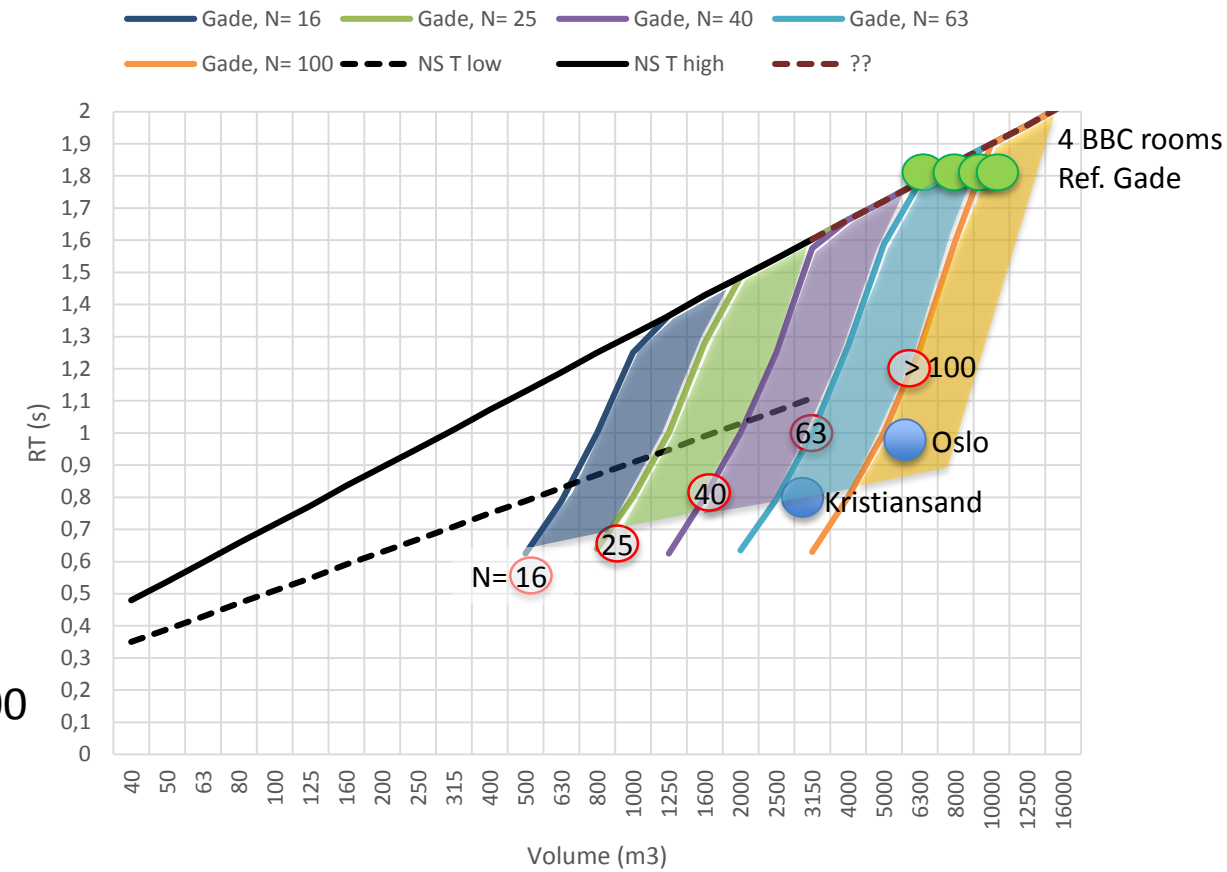
NS8178 T limits,
Un-reinforced music

Gade's 8m2Sa per musician

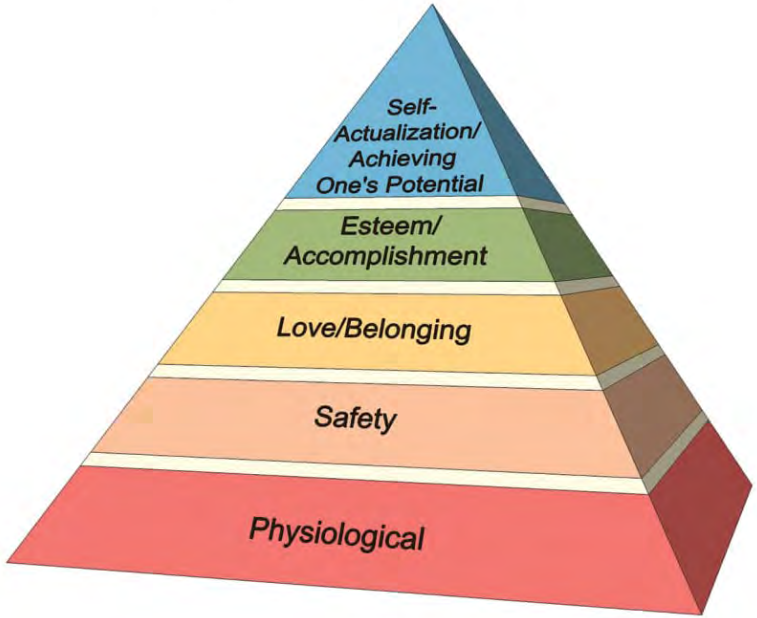
Gade's BBC examples

D-R=0dB cases with ensembles N=16 to N=100

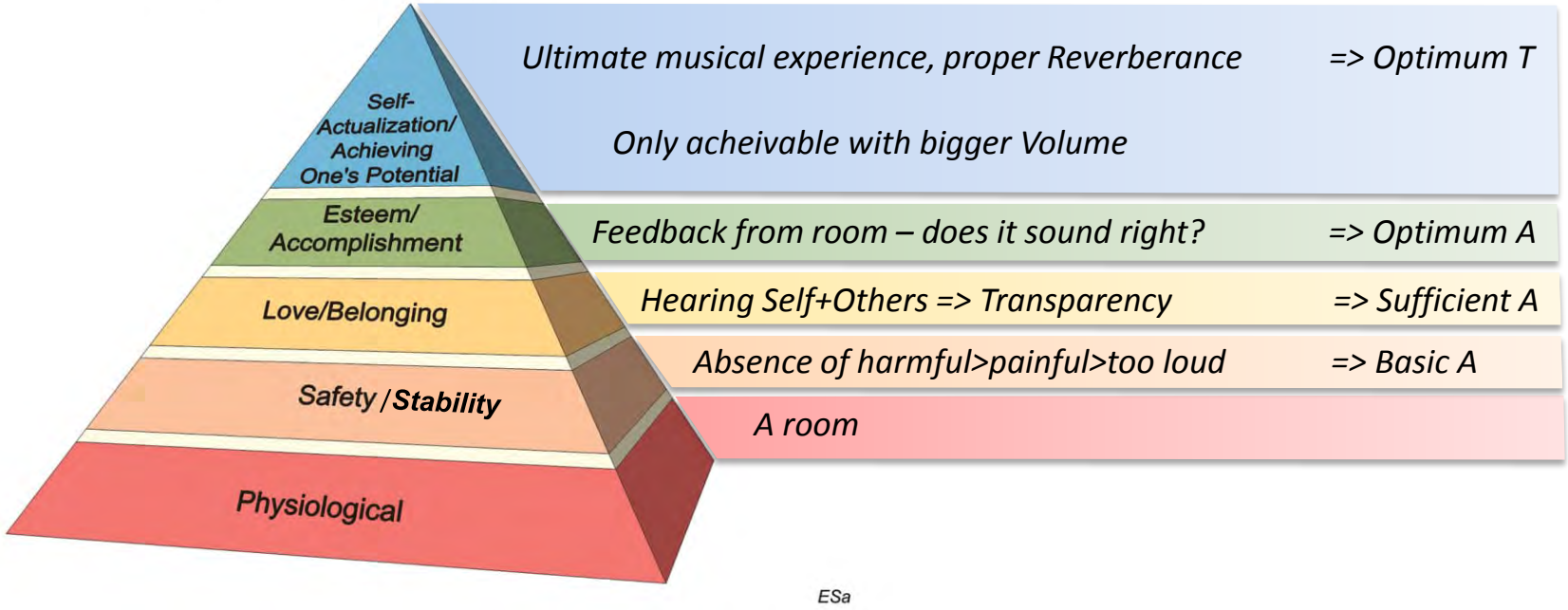
= preferred by musicians



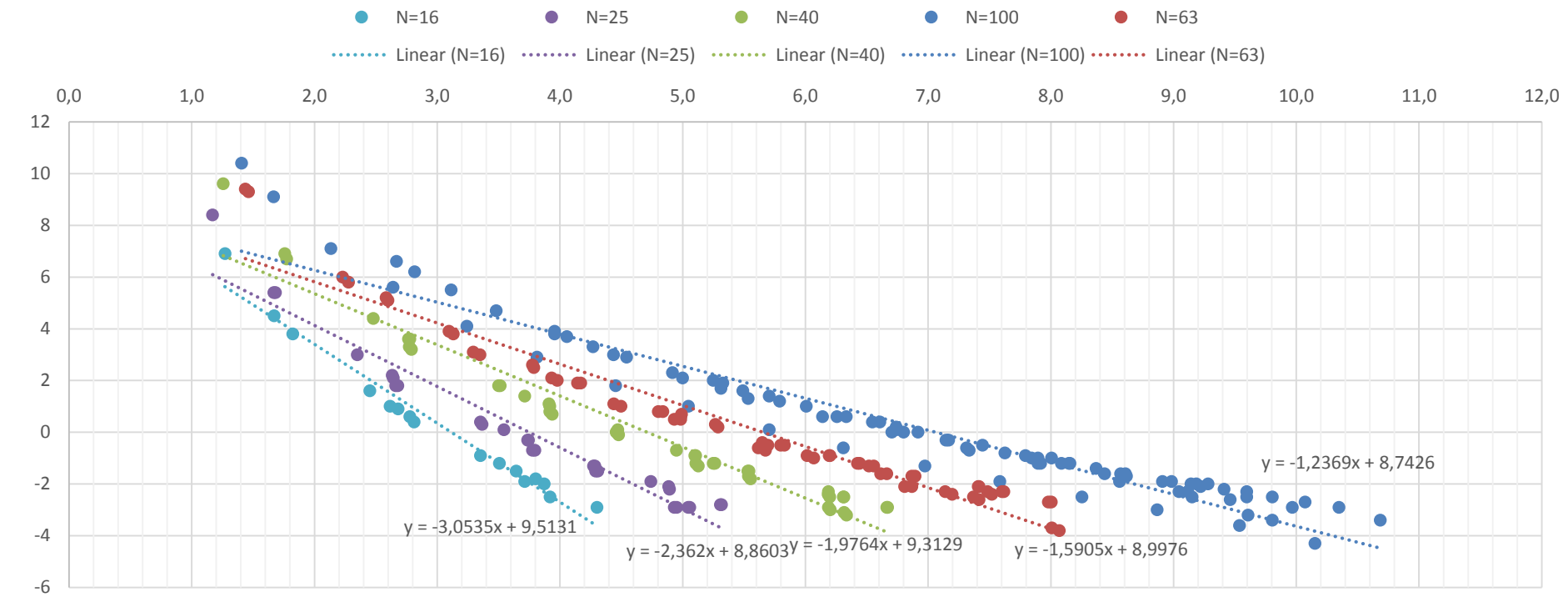
Maslow's Hierarchy of Needs



Musician's Hierarchy of Acoustical Needs



Simulations of D-R as function of distance *r*



Conclusions

Ensemble rehearsal rooms has special demands for combinations of N, V and T

Acoustical needs seems to be ordered in a Hierarchy

– *A*, or equivalent, *V/T* is a more basic need than *T* in itself

– In some cases where V/T is adequate, musicians are happy with «too low» *T*

Acoustical transparency requires *average(D-R)≈0 dB*

Suggested criteria V/N ≈ 50*T , in symphony orchestra, 1.5m2 floor per musician

This is equivalent to A/N ≈ 8m2Sa and would provide

– Transparency, *AT=average(D-R)≈0 dB*

– Loudness and sound exposure management

In further work, «good» and «bad» cases should be added to the V-T-diagram

Thank you for your attention

Related papers:

Sound exposure and the hearing of musicians by Dance and Dymock
The influence of Room Acoustic Aspects on the Noise Exposure of Symphonic Orchestra Musicians by Wenmaekers and Hak
A Model for the prediction of Sound Levels within a Symphonic Orchestra based on measured Sound Strength by Wenmaekers and Hak
Noise exposure of musicians: The own instrument's sound compared to the sound from others (paper) (presentation) by Wenmaekers and Hak
Rehearsal room acoustics for the orchestra musician, by M Skålevik
Consistency in music room acoustics (paper) (presentation) by M Skålevik
Level balance between Self, Others and Reverb, noise exposure and mutual hearing in orchestra musicians (paper) (presentation) by M Skålevik

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