Level balance between Self, Others and Reverb, and its significance to noise exposure as well as mutual hearing in orchestra musicians

by Magne Skålevik

This paper was presented at Euronoise 2015 in Maastricht

ABSTRACT

In order to gain more insight in ensemble issues as well as noise issues, it is proposed to analyze the sound at the ears of musicians in three components, namely the Dry Self, Dry Others and Reverb. Simulation in Odeon and several measurement series in different typical situations have been carried out during 2014. Dry Self represents 50-60% of the energy density at the ear of musicians in all situations investigated so far, except for violinists in individual rehearsal, where Dry Self represents approximately 80%. This means that commonly suggested noise and health measures in the musicians’ acoustical environment is not effective, but instead are likely to more harm than good to ensemble conditions. Suggested balance parameters Foreground-Background-Balance and Dry-Reverb balance exhibit consistent results through changing situations. These are interesting features will be pursued in further work, as they could potentially tie together podium acoustics and rehearsal room acoustics. 

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On noise exposure and mutual hearing in orchestra musicians

LEVEL BALANCE BETWEEN SELF, OTHERS AND REVERB
Noise? - NO
Sound? - YES
Outline

- Sound components at orchestra musician’s ear
- Simulations – violin in 4 different situations
- Measurements in orchestra musicians
- Corrective measures
- Conclusions
Sound at musician’s ear

Total sound = **Self** + **Others** + **Reverb**

- **Self** = anechoic sound from own instrument
- **Others** = anechoic sound from other instruments
- **Reverb** = reverberant sound from all instruments
## Components and Balance

<table>
<thead>
<tr>
<th>Component</th>
<th>Foreground-Background-Balance Components</th>
<th>Dry-Reverb-Balance Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self</td>
<td>Foreground</td>
<td>Dry</td>
</tr>
<tr>
<td>Others</td>
<td>Background</td>
<td></td>
</tr>
<tr>
<td>Reverb</td>
<td></td>
<td>Reverb</td>
</tr>
</tbody>
</table>
Components’ energy fractions example

- **Reverb all = 20%**
- **Dry others = 17%**
- **Dry self = 63%**

- **BACKGROUND = -4dB**
- **FOREGROUND = -2dB**

- **Foreground-Background = +2dB**
- **Dry - Reverb = 6dB**

- **REVERB = -7dB**
- **DRY = -1dB**
Significance of Components and Balance

- To a musician, Self, Others and Reverb could be
  - Important information (Signal)
  - Masker (Noise)
  - Harmfully loud
  - Harmless

- Self, Others and Reverb play ALTERNATING ROLES as Signal and Masker

- Level balance and prominent sound components
  - Crucial when choosing any correcting measures

- Poor Balance can drive musicians to play HARDER
  - Long term escalating effect
4 Odeon models
4 situations
in the orchestra musician's daily life

Individual rehearsal room
height=2.5-2.7m

Group rehearsal room
height=5.0m

Rehearsal Studio,
height=14m

Concert Hall,
height=18m
Simulated 4 situations violin

Ensemble play

Individual rehearsal
Dry-Reverb Balance Violin

All situations, 6-7dB is Good
Measurements in-ear

- Self, Others and Reverb calculated from measurements
Small rehearsal room

Big rehearsal room

Orchestra Rehearsal Studio

Opera House Orchestra Pit

T=0.4  Gr=25

T=0.7  Gr=15

T=1.0  Gr=8

T=2.1  Gr=6
At ear $L_{A,eq}$ (216s at ff)

- $L$ = Left ear canal entrance
- $R$ = Right ear canal entrance
- far = behind the back, i.e. screened from own instrument

3 ff parts, total duration 216s, Tchaikovski Swan Lake
Analysis: energy re self

Reverb all L+R
Dry others L+R
Dry self L+R

reh room
big reh room
studio
pit
Analysis: energy re self

Not good for individual rehearsal

- Reverb all L+R
- Dry others L+R
- Dry self L+R

reh room, big reh room, studio, pit
Analysis: energy fractions

Reverb fraction appears to be consistent - while self and others alternates in the dry part.

![Bar chart showing energy fractions in various settings.]

- Reverb all L+R
- Dry others L+R
- Dry self L+R

Settings:
- reh room
- big reh studio
- pit
Dry-Reverb Balance, Violin

- reh room
- big reh room
- studio
- pit

Balance (dB) vs.

Dry Reverb L+R
Violin: Rehearsal and Performance

Simulation - Odeon

<table>
<thead>
<tr>
<th>Reh room</th>
<th>Studio</th>
<th>Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>reverb</td>
<td>19%</td>
<td>17%</td>
</tr>
<tr>
<td>dry others</td>
<td>0%</td>
<td>21%</td>
</tr>
<tr>
<td>dry self</td>
<td>81%</td>
<td>62%</td>
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</tbody>
</table>

Swan Lake

<table>
<thead>
<tr>
<th>Reh room</th>
<th>Studio</th>
<th>Pit</th>
</tr>
</thead>
<tbody>
<tr>
<td>reverb</td>
<td>19%</td>
<td>20%</td>
</tr>
<tr>
<td>dry others</td>
<td>0%</td>
<td>29%</td>
</tr>
<tr>
<td>dry self</td>
<td>81%</td>
<td>51%</td>
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</table>

Beethoven 5th

<table>
<thead>
<tr>
<th>Reh room</th>
<th>Studio</th>
<th>Stage</th>
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</thead>
<tbody>
<tr>
<td>reverb</td>
<td>13%</td>
<td>22%</td>
</tr>
<tr>
<td>dry others</td>
<td>0%</td>
<td>25%</td>
</tr>
<tr>
<td>dry self</td>
<td>87%</td>
<td>54%</td>
</tr>
</tbody>
</table>

Long time average

219 s

420 s
Rehearsal and Performance

Oboe  Trumpet  Violin

Measurements by H Rydland, NTNU 2014
Oboe, Trumpet, Violin averages: Rehearsal (R) and Stage Performance (P)

Measurements by Helena Rydland, NTNU 2014
<table>
<thead>
<tr>
<th></th>
<th>Oboe Stage 1</th>
<th>Oboe Stage 2</th>
<th>Oboe Stage 3</th>
<th>Oboe Stage 4</th>
<th>Trp Stage 1</th>
<th>Trp Stage 2</th>
<th>Trp Stage 3</th>
<th>Trp Stage 4</th>
<th>Vln Stage 1</th>
<th>Vln Stage 2</th>
<th>Vln Stage 3</th>
<th>Vln Stage 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>reverb</td>
<td>15%</td>
<td>10%</td>
<td>15%</td>
<td>21%</td>
<td>15%</td>
<td>2%</td>
<td>2%</td>
<td>11%</td>
<td>2%</td>
<td>26%</td>
<td>12%</td>
<td>35%</td>
</tr>
<tr>
<td>dry others</td>
<td>33%</td>
<td>44%</td>
<td>51%</td>
<td>39%</td>
<td>41%</td>
<td>58%</td>
<td>62%</td>
<td>31%</td>
<td>70%</td>
<td>54%</td>
<td>32%</td>
<td>20%</td>
</tr>
<tr>
<td>dry self</td>
<td>52%</td>
<td>45%</td>
<td>34%</td>
<td>40%</td>
<td>44%</td>
<td>41%</td>
<td>36%</td>
<td>67%</td>
<td>19%</td>
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<td>42%</td>
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<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
From measurements w/wo Others, concert hall

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Brahms N=3</th>
<th>Ravel N=4</th>
<th>Ravel N=5</th>
<th>misc N=5</th>
<th>misc N=3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reverb</td>
<td>9%</td>
<td>9%</td>
<td>5%</td>
<td>13%</td>
<td>52%</td>
</tr>
<tr>
<td>Others</td>
<td>70%</td>
<td>61%</td>
<td>52%</td>
<td>30%</td>
<td>16%</td>
</tr>
<tr>
<td>Self</td>
<td>21%</td>
<td>30%</td>
<td>43%</td>
<td>57%</td>
<td>33%</td>
</tr>
</tbody>
</table>

Measurements by Helena Rydland, NTNU 2015
Invisible sound shield

Provide better Foreground-Background-Balance
Sound shield for Brass protection
Sound shield for Brass protection

Improving Foreground-Background-Balance
But not reducing exposure level (How come?)
Hearwig shield

Brass active

- in-ear LpA = 103.1
- outside EarWig LpA = 99.2
Passive, shielded clarinet player

Brass active

- outside hearwig 96 LpA(dB)
- R in Ear 97 LpA(dB)
Active, shielded clarinet player

Brass active

- in-ear $L_{PA} = 103.1$
- outside EarWig $L_{PA} = 99.2$
Sound shields, Insertion Loss, lab-data

Insertion Loss Falko S 300 and Hearwig

Parameters:
- IL (dB)
- Frekvens (Hz)

Graph shows the insertion loss for Falko S 300 and Hearwig across different frequencies.
# Ear plugs

<table>
<thead>
<tr>
<th>Who to protect?</th>
<th>Harmful Source:</th>
<th>ER•9</th>
<th>ER•15</th>
<th>ER•25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small strings</td>
<td>Own instrument, other strings</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Large strings</td>
<td>Brass</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Woodwinds</td>
<td>Brass, percussion</td>
<td></td>
<td></td>
<td>•</td>
</tr>
<tr>
<td>Brass</td>
<td>Own instrument, other brass</td>
<td></td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Flutes</td>
<td>Percussion</td>
<td></td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Percussion</td>
<td>Own instruments, other percussion</td>
<td></td>
<td>•</td>
<td>•</td>
</tr>
</tbody>
</table>

Etymotic 9dB, 15dB, 25dB

[Graph of Earplug Attenuation]

Multimax and cotton ball (custom)

[Graph of Lyddemping: Bomullskuler, kontra multimax ørepropper]

Reduksjonal (dB)

5  10  15  20  25  30

500 1000 2000 3000 4000 5000 6000 8000

Frekvens (Hz)
4000+ hours of dosimetry, $\mu$ and $\sigma$, Queensland / O’Brien 2004-2007
Conclusions

- Self, Others and Reverb have been defined
  - Simulations and measurement examples presented

- Relevant for artistic and hearing issues
  - In rehearsal as well as performance situations

- Self-fraction and balance varies with instrument type
  - Due to ear-to-instrument distance $r'$ and orchestral neighbourhood
  - Strong Self-fraction seen in violin due to small $r'$ and quiet neighbourhood

- Key data should be collected in large amounts

- There are measurement technical issues

- Sound shields alter balance but not exposure

- Ear plug attenuation should not be excessive

- Future work to include more instruments and statistic analysis
Thank you

More info?

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

www.akutek.info

magne.skalevik@brekkestrand.no
More free sharing in acoustics available on www.akutek.info

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
Level balance between Self, Others and Reverb, and its significance to noise exposure as well as mutual hearing in orchestra musicians (paper) (presentation) by M Skålevik
Rehearsal room acoustics for the orchestra musician, by M Skålevik
Consistency in music room acoustics (paper) (presentation) by M Skålevik

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