The Subjective and Objective Evaluation of Room Correction Products

Sean E. Olive, John Jackson, Allan Devantier, David Hunt, and Sean M. Hess

R&D Group, Harman International
Overview

Motivation

Experiment

Results

Conclusions
Motivation

Acoustical interactions between loudspeakers are a significant source of variance in the playback chain.

**Low frequencies** (< 500 Hz): room modes, solid angle gain/boundary effects

**Higher frequencies** (> 500 Hz): room reflections are dominant effect but room correction cannot fix this; this is mostly “loudspeaker correction” - not “room correction”
The measured impulse response dynamic range is typically 60dB, ranging from 40dB to 70dB. The dynamic range is determined by noise produced by the measurement apparatus and the room in which the measurement has been taken.

The listening distance has been analyzed for those speakers having their acoustical axis directed toward and impulse responses recorded at the engineer's position (250 measurements). The distances measured from the time-of-flight recorded in the impulse response range from 1.2 meters to 4.2 meters. The average listening distance is 2.49 meters. The distances estimated in this manner correspond to actual listening distances and can be taken to indicate the listening distance spread for main monitors including both front and rear monitors in multichannel audio configurations. The mean distance for individual channels is very close to equidistance for 5-channel setups and there was no significant systematic difference between the front speaker distance and the rear speaker distance.

Speakers in larger rooms tend to be placed higher than ear level because of space constraints. Table 3 gives the height of installation relative to the engineer's position and a possible vertical tilt as a function of the room size. The speakers are not necessarily tilted down toward the listener when they are installed high. In small rooms less than 30% of speakers placed high relative to the engineer are tilted down while in large rooms this percentage increases to 55%.

Horizontally the speakers in small rooms were invariably aimed toward the engineer's position (Table 4). As the room size increases, more speakers are aimed toward the back of the room and not toward the engineer. In large rooms 10% of speakers are not aimed at the listening area.

The flatness of the third octave smoothed frequency response measured in-situ at the engineer's position, also called the operational room response, shows an increasing spread toward low frequencies. The 50% variation for frequencies f > 130Hz and 90% variation for frequencies f > 500Hz is within the proposed limits for monitoring spaces [5]. We can see the amplitude responses generally suffering a loss of level above 16kHz. Only 5% of rooms show a straight response up to 20kHz. The large notch at 4.5kHz in Fig. 1 in the minimum curve is produced by a strong first order ceiling reflection in two measured loudspeakers, demonstrating that very non-ideal frequency responses exist in modern rooms.
Experiment

**Research Questions:**

1) To what extent do room correction products improve or degrade the overall quality of reproduced sound based on listener preference and spectral balance ratings?

2) Can the subjective ratings of the room correction products be explained by objective measurements such as the combined in situ loudspeaker/room frequency response?
### Independent Variables

<table>
<thead>
<tr>
<th>Independent</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room Correction</td>
<td>RC1</td>
</tr>
<tr>
<td>Products (6)</td>
<td>RC2</td>
</tr>
<tr>
<td></td>
<td>RC3</td>
</tr>
<tr>
<td></td>
<td>RC4 (No Room Correction)</td>
</tr>
<tr>
<td></td>
<td>RC5</td>
</tr>
<tr>
<td></td>
<td>RC6</td>
</tr>
<tr>
<td>Programs (3)</td>
<td>JW  - Jennifer Warnes, “Bird on a Wire”</td>
</tr>
<tr>
<td></td>
<td>TC  - Tracy Chapman, “Fast Car”</td>
</tr>
<tr>
<td></td>
<td>JW  - James Taylor, “That’s Why I’m Here”</td>
</tr>
<tr>
<td>Observations (3)</td>
<td>O1, O2 and O3</td>
</tr>
</tbody>
</table>
## Room Correction Products

<table>
<thead>
<tr>
<th>Product</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anthem Statement D2 Processor</strong></td>
<td>$7000</td>
</tr>
<tr>
<td><strong>Audyssey Room Equalizer</strong></td>
<td>$2500</td>
</tr>
<tr>
<td><strong>Harman 1 (6 seats)</strong></td>
<td>NA</td>
</tr>
<tr>
<td><strong>Harman 2 (optimized seat)</strong></td>
<td>NA</td>
</tr>
<tr>
<td><strong>Lyngdorf DPA-1</strong></td>
<td>$5500</td>
</tr>
<tr>
<td><strong>No equalization</strong></td>
<td>Free</td>
</tr>
</tbody>
</table>
Loudspeaker

sound power problem

B&W 802N
Subwoofer

4th order LR @ 80 Hz  JBL HB5000
Harman International Reference Listening Room

see Sean E. Olive “A New Reference Listening Room for Consumer, Professional, and Automotive Audio Research,” 126th AES Convention, Munich, (May 2009)
Room/Speaker/Listener Setup

Calibrations for each room correction product performed based on manufacturer's user manual
Why Mono Comparisons?

Listeners are more discriminating of room correction in mono than stereo or surround

Olive, Devantier & Hess,” Comparison of loudspeaker-room equalization preference for multichannel, stereo, and mono reproductions: Are listeners more discriminating in mono?” AES, Convention, Munich (May 2008)
Dependent Variables

Preference

Spectral Balance

Comments
Listening Test Method

Room corrections loudness normalized within 0.1 dB according to CRC loudness meter

8 trained listeners with normal hearing

MUSHRA - (no EQ is hidden reference)

Double-blind

Room corrections and program order randomized
Results
Mean Preference Rating for Room Correction

No better or Worse than No EQ
Perceived Spectral Balance

Too Much

Ideal

Too Little

Less Preferred

Frequency (Hz)

Spectral Balance

RC1

RC2

RC3

RC4

RC5

RC6

33
88
236
632
1700
4500
12000
## 2004 Consumer Clinic Test – Sedan

- \( n = 310 \) Untrained, \( n = 9 \) trained

## 2003 Consumer Clinic Test – Sedan

- \( n = 245 \) Untrained, \( n = 11 \) trained

### Room Correction

<table>
<thead>
<tr>
<th>Room Correction</th>
<th>Colored</th>
<th>Harsh</th>
<th>Thin</th>
<th>Muffled</th>
<th>Forward</th>
<th>Bright</th>
<th>Dull</th>
<th>Boomy</th>
<th>Full</th>
<th>Neutral</th>
<th>Preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC1</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>13</td>
<td>38</td>
<td>6.95</td>
</tr>
<tr>
<td>RC2</td>
<td>5</td>
<td>0</td>
<td>11</td>
<td>0</td>
<td>4</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>25</td>
<td>6.63</td>
</tr>
<tr>
<td>RC3</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>35</td>
<td>17</td>
<td>9</td>
<td>5.97</td>
</tr>
<tr>
<td>RC4 (no EQ)</td>
<td>27</td>
<td>0</td>
<td>6</td>
<td>19</td>
<td>2</td>
<td>2</td>
<td>13</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>3.66</td>
</tr>
<tr>
<td>RC5</td>
<td>10</td>
<td>9</td>
<td>35</td>
<td>0</td>
<td>13</td>
<td>19</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>3.52</td>
</tr>
<tr>
<td>RC6</td>
<td>35</td>
<td>18</td>
<td>31</td>
<td>11</td>
<td>8</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.03</td>
</tr>
</tbody>
</table>

### Correlation w. Preference

|                 | -0.9   | -0.86  | -0.75  | -0.6   | -0.59  | -0.32  | -0.24 | 0.36  | 0.79 | 1       |

### Comments

- **Less Preferred**

---

**Text**

---
Comments

Less Preferred

Frequency Count For Attribute

Room Correction

<table>
<thead>
<tr>
<th>Room Correction</th>
<th>Neutral</th>
<th>Full</th>
<th>Boomy</th>
<th>Dull</th>
<th>Bright</th>
<th>Forward</th>
<th>Thin</th>
<th>Muffled</th>
<th>Full</th>
<th>Boomy</th>
<th>Frequency Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>44</td>
</tr>
<tr>
<td>RC2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>44</td>
</tr>
<tr>
<td>RC3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>88</td>
</tr>
<tr>
<td>RC4 (no EQ)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>66</td>
</tr>
<tr>
<td>RC5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>110</td>
</tr>
<tr>
<td>RC6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Objective Measurements
Objective Measurements

(1) In-room amplitude of loudspeaker spatially-averaged over 6 listening seats

(2) In-room amplitude of loudspeaker spatially-averaged at the primary listening seat

Frequency resolution is 48 ppo; 1/6-octave smoothing
Average Magnitude Response Over 6 Seats

Less Preferred
Average Magnitude Response at Primary Listening Seat

Less Preferred
Perceived versus Measured Spectral Balance

Flat in-room response is **not** the preferred target
Average Response at Main Seat

Bass Differences

Sound Power Differences
Conclusions (1)

Large differences in perceived sound quality preferences among commercial room correction products.

When done well, room correction can significantly improve the quality of sound production.

However, one room correction product did no better than “no correction,” and another did significantly worse.
Preference is strongly correlated to spectral balance and comments

Less preferred products had less smooth and extended in-room frequency responses; this was associated with more negative comments related to lack of bass (thin), brightness, and coloration.
Conclusion (3)

In-room measurements spatially-averaged around the primary listening seat are good indicators of listeners’ preferences, perceived spectral balance, and comments.

Flat in-room response is not the optimal target response (program may be a nuisance variable).
Thank you!

For more information contact:
sean.olive@harman.com