From Electro Acoustic Testing over Perceptual Testing to the World of Affective Measurements

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“The world of sound lost its virtue with the advent of electronic music!”

Birger Schneider
For many years the main focus for designers of audio systems have been to obtain a close reproduction of sounds of the "real world".

References were "absolute" sounds like:
- Violin
- Flute
- Trumpet
- etc.

About As Good As It Gets
• Synthesized music has changed the human perception of sound.

• As a musical instrument, the computer has unlimited potentials for uttering sound.

• The musical universe is now circumscribed by man’s perceptions and creativity.

• However, we have lost the common reference of sound.
• The reality is, of course, much more complex, e.g. related to:
  – Digital music and extended use of compression has had significant influence.
  – New sounds, e.g. frequent use of audible distortions in sound.
  – Effects of masking in audio.
  – Etc.
• Traditional measurements of electro acoustics are no longer sufficient for audio products.

• Today’s test of audio products during development also requires:
  – Perceptual measurements
  – Affective measurements
Three Types of Analysis of Sound Systems

- **Electro acoustical** measurements:
  - Capture signal using microphone and electronic measurement system.
  - Analyze: frequency response, THD, SNR, etc.

- **Perceptual** Measurements (is the sound correct?):
  - Capture signal using microphone and electronic capture system.
  - Use *expert panels* (people) in the subjective measurements (rating of defined parameters)

- **Affective** measurements (do I like the sound?)
  - Capture signal using microphone and electronic capture system.
  - Use *non-expert panels* (people) in the subjective measurements (how well do I like the sound system)
SOUND, PERCEPTION AND PREFERENCE – THE FILTER MODEL

Physical measurement

Perceptual measurement

Affective measurement

Filter 1, the senses

Filter 2, non acoustical factors

Physical stimulus

Perceived stimulus

Likes/dislikes

Sensory sensitivity and selectivity

Expert panels, trained listeners

Mood

Context

Emotion

Background

Expectation

Technical Measuring equipment

Objective

Repeatable pseudo objective

Subjective

Consumers, "naïve users"
SOUND, PERCEPTION AND PREFERENCE – THE FILTER MODEL

**Physical measurement**
- Physical stimulus
  - M1
  - Sensory sensitivity and selectivity

**Perceptual measurement**
- Perceived stimulus
  - Perceptual model
  - Objective
  - Repeatable pseudo objective

**Affective measurement**
- Likes/dislikes
  - Mood
  - Context
  - Emotion
  - Background
  - Expectation
  - Subjective
• The industry making sound systems has strong focus on delivering the “sound” that their target groups desire.

• Affective sound is becoming a strong differentiator in markets like consumer electronics, automotive and telecom.

• Affective sound is:
  – Highly subjective
  – Varies significantly between different users groups
  – Depends on many subjective parameters, e.g. music preference, mood, sound system technology, and many others

• Affective sound in relation to sound systems basically relates to:
  “Do you like the sound?”
Ann C. Noble is a sensory chemist and retired professor from the University of California, Davis.
The Power of International Co-operation

The European Sensory Network (ESN) is a powerful international network of leading research institutions and industrial partners at the cutting edge of sensory and consumer sciences. Founded in 1989 to meet the challenge of the rapidly developing science of sensory analysis within Europe.

Today, the European Sensory Network brings together 26 member organizations acting in 17 European countries, and four non-European countries.
• Sensory test applications are handled in a structured and well defined manner across many industries.

• In *perceptual* and *affective* audio measurements it is common practice to use two types of panels of people:
  – Sensory panels = Expert panels (perceptual testing)
  – Consumer panels = “Naïve” users (affective testing)

• DELTA typically uses panels of 20-25 people depending on the agreement with customers (confidence, etc.)
• Definition of the common set of test attributes is essential prior to a perceptual or affective test.

• In requirements engineering, requirements elicitation is the practice of collecting the requirements of a system from users, customers and other stakeholders.

• Use the “Semantic Space of Sounds” to select, e.g. 6-10 words to describe test target (can use special lexicon >1000 words).
  – Sensory group defines the attributes and sub descriptions
  – Consensus!
Using expertise in perception using **eyes**, **ears** and **touch**, to apply **sensory** and **consumer** evaluation techniques, to better explain product perception and user perspectives, within an international marketplace.

DELTA SenseLab is an independent test laboratory specialized in performing listening tests in a variety of domains.
Listening Test with Loudspeakers
Commonly used test types

- **ITU-R BS.1534-1** (a.k.a. MUSHRA)
  - Intermediate audio quality testing

- **ITU-R BS.1116-1**
  - High quality audio codec testing
Assessor attribute training

Listening set-up for headphones
Sound Profile

-0.2
0.0
0.2
0.4
0.6
0.8
1.0
Loudness

Sharpness

Roughness

Fluctuation

Tone prom.

Impulse prom.

Passive attenuation

Standard

10 dB active atten. of tone

Passive + active attenuation
Sound Profile

- Loudness
- Sharpness
- Roughness
- Fluctuation
- Tone prom.
- Impulse prom.

Standard

Passive attenuation

10 dB Active atten. of tone

Pasive + active attenuation
Sound Profile

-0.2  0.0  0.2  0.4  0.6  0.8  1.0
Loudness

Impulse prom.
Sharpness
Tone prom.
Roughness
Fluctuation

Standard
Passive attenuation
10 dB Active atten. of tone
Pasive + active attenuation
• Test facilities
  – Listening room according to EBU 3276 and ITU-R BS.1116-1
  – 2 IAC listening booths
  – Anechoic chambers (up to 10x10x10m)

• Can be setup for
  – Multichannel reproduction
  – Real device testing

• Expert panels
  – 30 experienced or expert assessors (ISO 8586-2)
  – Screened and selected
  – Audition and vision
  – Acuity, ability and repeatability

  – Access to naïve listeners/consumers worldwide
Automatic Statistical Analysis

- Mean and confidence intervals
- ANOVA model
- TUKEY HSD
- Interaction plots
- Assessor performance
- Hierarchical multiple factorial analysis (HMFA)
- Box-plots
- Density plots
- Spiderplots
- Output as jpg
- Access to raw data file
• Fletcher & Munson, Bell Labs 1933
• Robinson & Dadson, 1956
• Original ISO 226
• Revision in 2003, ISO 226:2003

Fletcher-Munson Curves

Sound Pressure Level (dB SPL)

Equal-loudness contours (red) (from ISO 226:2003 revision)
Original ISO standard shown (blue) for 40-phon
Speech Recognition

- Speech in telephony systems 300 Hz to 3400 Hz
- Fundamental speech frequencies fall below the “voice frequency” band above.

![Graph showing frequency vs. age]
• In all hearing sensations, masking plays an important role in both the frequency and time domains.

• Example: *Low frequency noise*
  If a bus is passing two persons having a conversation, the speaker must raise his voice or wait, until the bus has passed.

• In *music*, different instruments can mask each other, and softer instruments only become audible the louder instruments pause.
• Auditory masking occurs when the perception of one sound is affected by the presence of another sound.

• Masking is typically described in terms of the minimum sound-pressure level (SPL) of a test tone (typ. pure tone) that is audible in the presence of a **masker**.
Auditory Masking

Source: McGill Physics, Canada
• Generally, playing a single tone masks tones of very nearby frequencies if the nearby pitch is more than **20 dB softer**.

• **Masking is stronger on the high frequency side** of the loud tone than on the low frequency side. That is, a deep, loud tone covers up high pitched, soft tones, but a high pitched, loud tone does not cover up deep, soft tones very much.

• Very loud tones have funny effects.

• Noise with many frequencies masks more effectively than pure tones.
• For some categories of PA-Sound systems, concert systems, low frequencies are intentionally amplified.

• Additional auditory masking will result.

• Result: Difficult to hear vocal text and music dominated by lower frequency rumble.

<table>
<thead>
<tr>
<th>Type of Concert</th>
<th>Low frequency sound level lift</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classic music concerts</td>
<td>0 dB</td>
</tr>
<tr>
<td>Jazz concerts</td>
<td>6 dB</td>
</tr>
<tr>
<td>Pop music concerts</td>
<td>12 dB</td>
</tr>
<tr>
<td>Rock, hip-hop concerts</td>
<td>15-20 dB</td>
</tr>
</tbody>
</table>
• Hip-Hop, electronic music vs. rock music
• A loud sound can mask soft sounds, even if they come up to 0.4 seconds after the loud sound turns off.
• A loud sound can mask a soft sound if it turns on within 0.04 seconds of the start of the soft sound.
• A loud tone played only in one ear can mask a soft tone played only in the other ear.
• Denmark has a lead position in audio products and solutions.
• In Denmark more than 2500 companies in audio related Biz.
• 21 largest in sound technology, employed 18,000 people (2006) turn-over DKK 20,4 billion, export 73-97%.
• Many perception-and cognitive-related aspects of sound technology need to be resolved
  
  **DI ITEK Position paper**

• A developer of audio products is blindfolded, if there are no clear objective targets.
  
  *Niels Ole Knudsen, Widex*

• DELTA is about to start a new R&D project (2013-2015):
  
  **RK-04: Competence Center for Reproduced Sound**
• The goal is to study and understand how an audio reproduction chain could produce a non-linear sound that achieves a desired set of user preferences.

• Each “domain” of speech, audio and music may have different models and different user preferences.

• Goals are to identify, understand and then deliver models for these domains.

• Research models to process information to map from:
  – Physical (electro acoustic) to perceptual
  – Perceptual to preference (affective)
Thanks for your interests!

Any questions?