LEDucation

Designer Light Forum

Integration of Acoustic Control in Lighting Fixtures

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Learning Objectives

At the end of this course, participants will learn about:

1. Effects of noise in the workplace
2. Basics of acoustics
3. Quality of sound environment
4. Effective integration of acoustic control in lighting fixture design

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1. Effects of noise in the workplace

1. Renaissance of Office Design
2. Collaboration vs Concentration
3. Workplace Wellbeing
4. Psychological and Physiological affects of Noise

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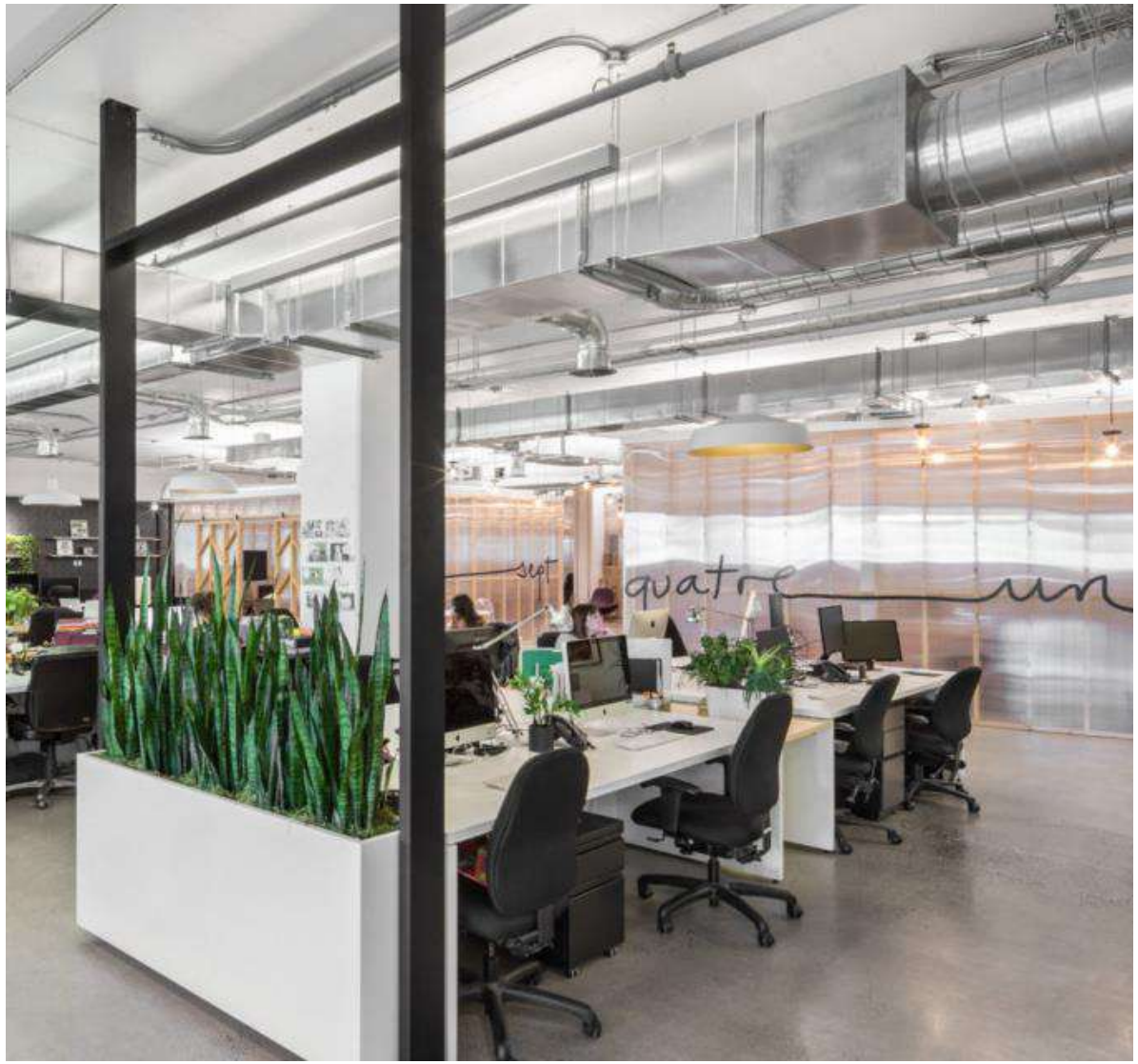
RENAISSANCE OF OFFICE DESIGN

- Office becoming narrative vehicle for company brand
- Co-work and public places are now designed for collaboration, creativity and innovation
- Relaxed, inviting, engaging and comfortable commercial spaces are the current trend - home and health are built into the environment
- Wellness design: LEED certification, Well Building Institute



Credit: Attraction Media (Montreal)

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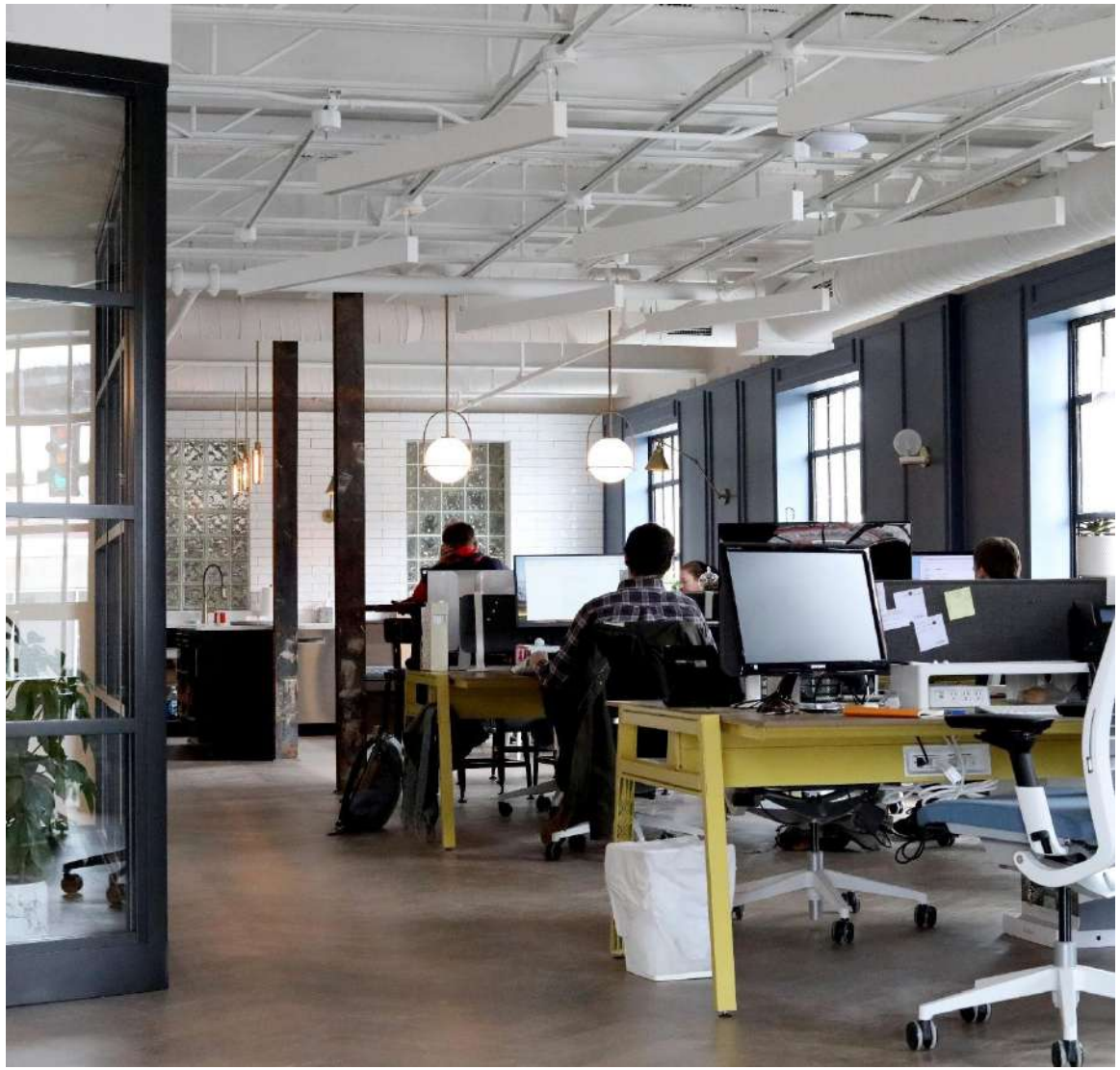

Credit: Benjamin Child

ACOUSTIC CHALLENGES

- Unfinished elements: ceiling or walls
- Larger windows in building and glass wall office or conference room
- Harder surfaces especially for flooring
- Removal of cubicles and wall partitions to create open office areas

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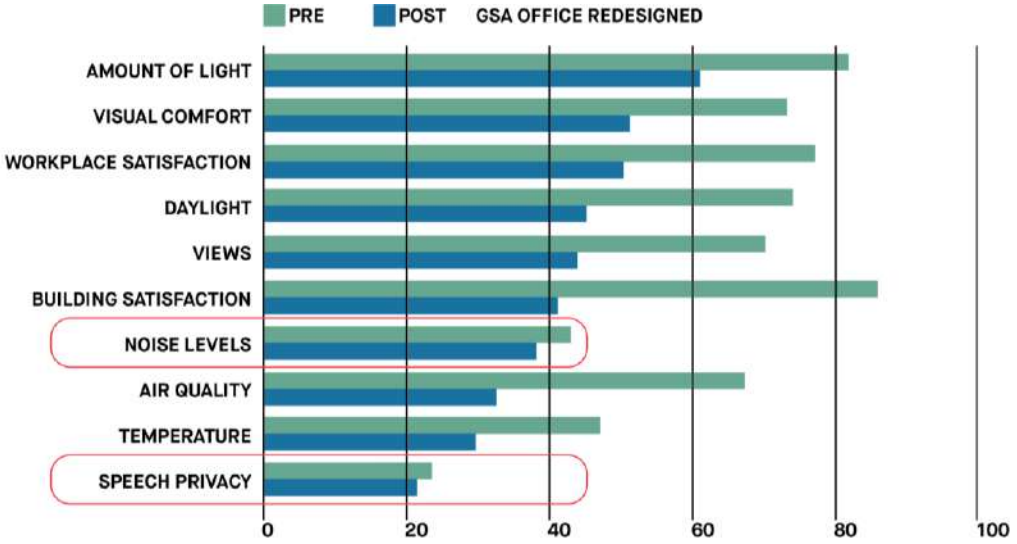
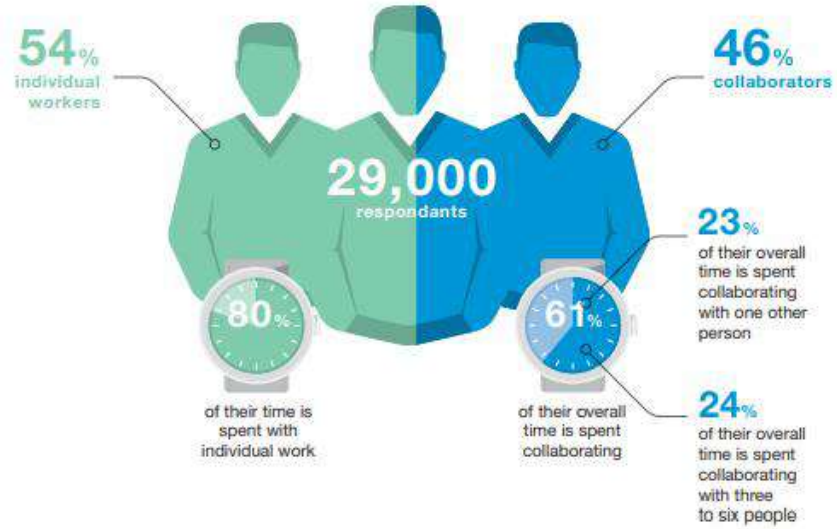
COLLABORATION VS CONCENTRATION

- Open office design = open concepts
- Typical office design fluid between collaborative and concentrated spaces

➢ Typical open office > 60-65 dB
➢ Ideal concentration work = 45-55 dB



Credit: GSA – Sound Matters (2012)



Credit: 360.steelcase.com

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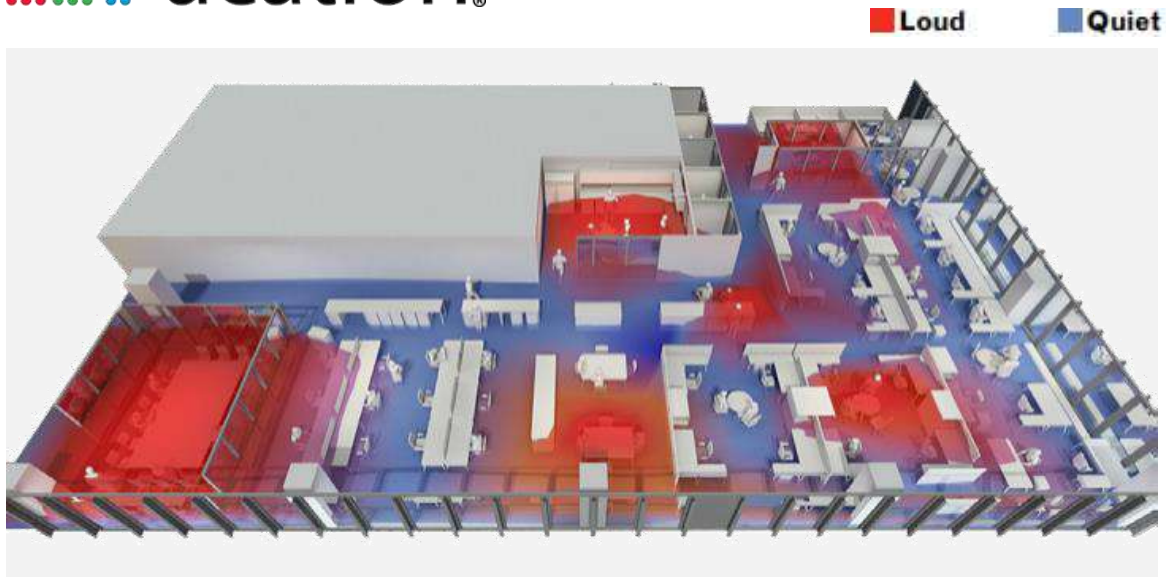

WORKPLACE WELLBEING

"Sustaining a healthy physical and mental state over time, in a supportive material and social environment."

- BEATRIZ ARANTES, *Senior Researcher, Steelcase WorkSpace Futures*

- **Environmental Noises:** HVAC, office machines, poor sound masking
- **Peoples voices:** biggest contributor to "unwanted noise"
- Noisy environments worse with time *(Lombard Effect)*
- Speech Privacy = productivity, comfort & legal
- Acoustics integrated in WELL & LEED Standards
  - OSHA Permissible exposure limit = 90 dB
  - OSHA Action level @ 85 dB

Credit (Top): GSA – Sound Matters 2012 (Bottom): AirBnB San Francisco

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Credit: Alex Kotliarskyi

PSYCHOLOGICAL/PHYSIOLOGICAL EFFECTS

"Noise puts a burden on our hearts and brains, as well as our ears."

- ***Dr. Wolfgang Babisch,*** *Lead Researcher, German Environmental Agency*

- Bandwidth capacity = 1.6 Humans
- We cannot control input – no earlids
- Physical effects incl. hypertension, cardiovascular disease, impaired cognition and annoyance *(Steelcase)*
- Workplace health and productivity can suffer as much as 66% *(Julian Treasure, Sound Agency)*

2. Basics of acoustics

1. Acoustic for lighting people
2. NRC
3. Reflection
4. Absorption
5. Speed
6. Reverberation
7. Reverberation time

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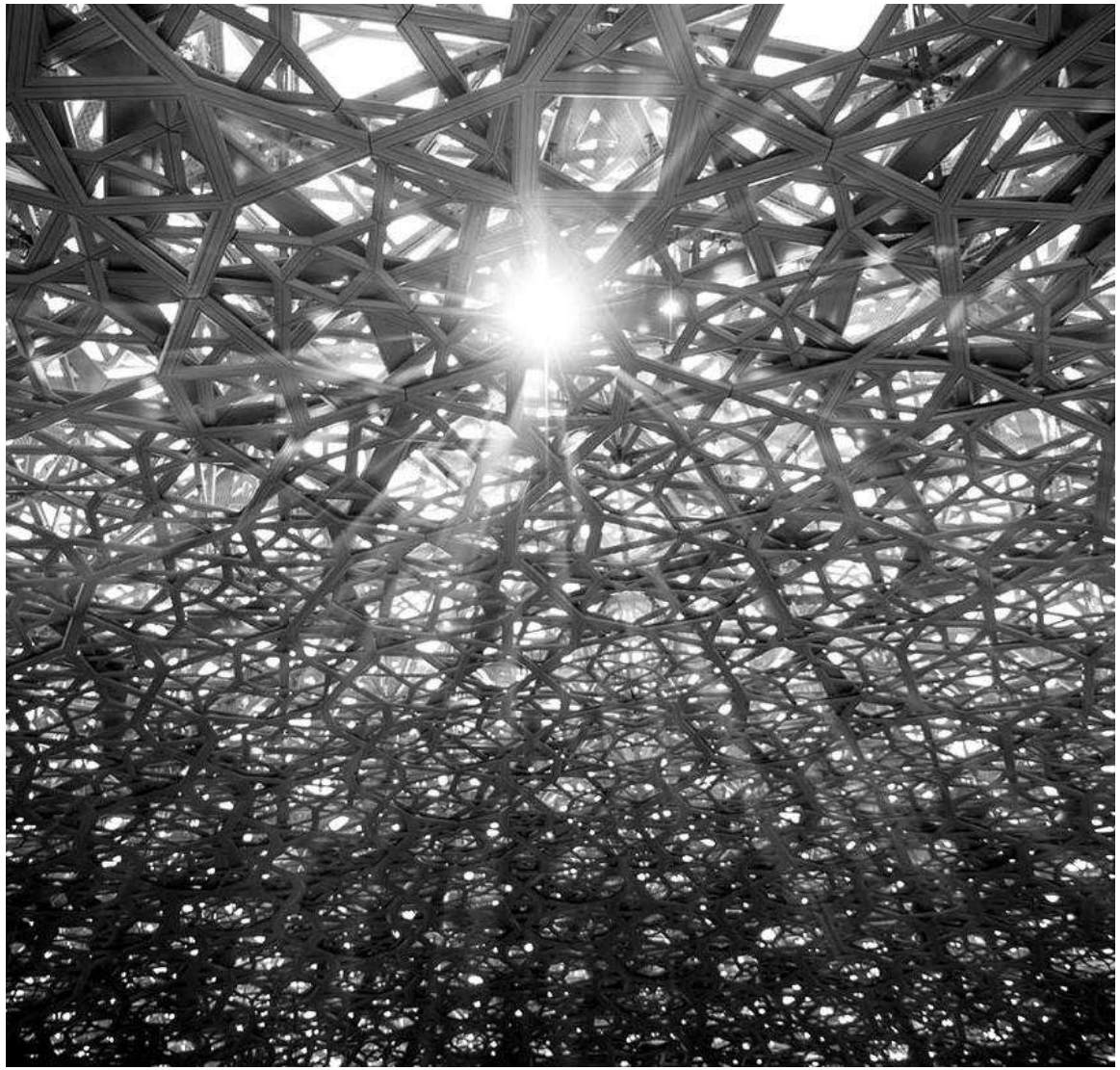
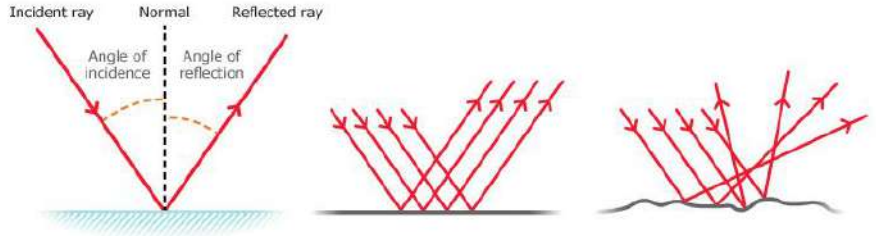


Credit: Ateliers Jean Nouvel

ACOUSTIC FOR LIGHTING PEOPLE:

- Frequency / Pitch - like CCT
  - 20-20,000 Hz @ +10dB
  - Human speech 250-8000 Hz
- Intensity / Loudness - like Lumens
  - Whisper = 25 dB
  - Motorbike / Truck = 90- 110 dB (discomfort)
- Sound waves perform like Light rays
  - Absorption, reflection, transmission, interaction, directional, degrading



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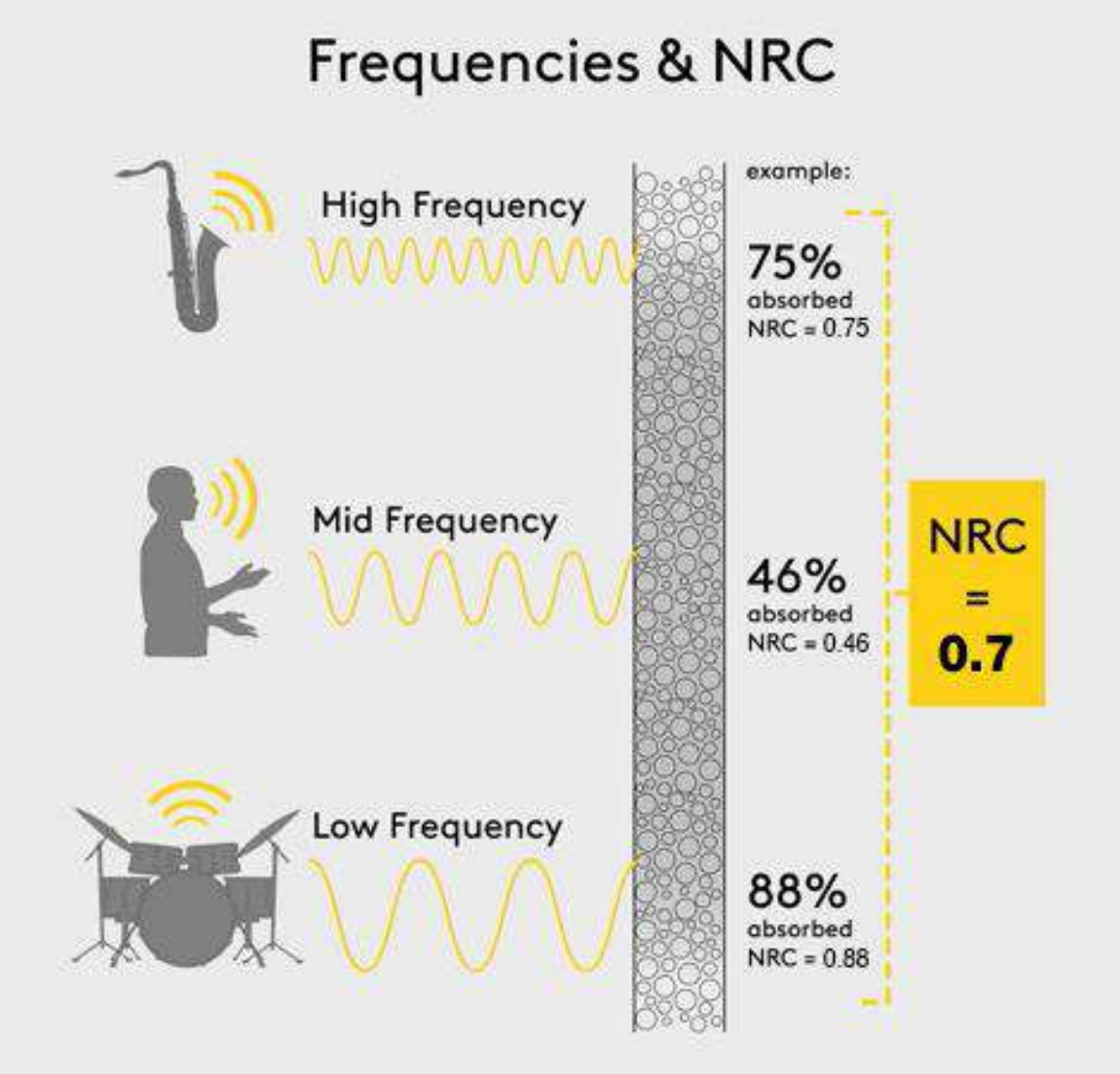

Credit: PLN Group

MESUREMENT STANDARDS

NRC (Noise Reduction Coefficient): most commonly used to rate acoustical properties of ceiling tiles, baffles, office screens and wall panels.

Sound Absorption is measured in m^2 of "absorption area." Absorption Coefficient is the sound absorption area observed in the test, divided by the area of test surface covered by the test sample.

Sabins are measured in Inch-pound units of "absorption area". (which approximated square feet of "open window")

Average (nearest 0.05) of the absorption coefficients for a specific material and mounting condition determined at the octave band center frequencies of 250, 500, 1000 and 2000 Hz

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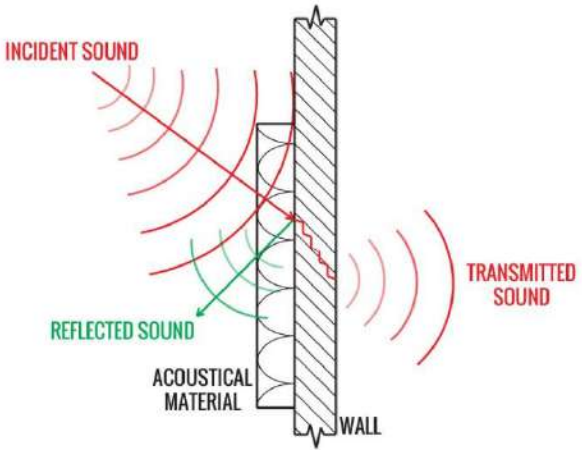
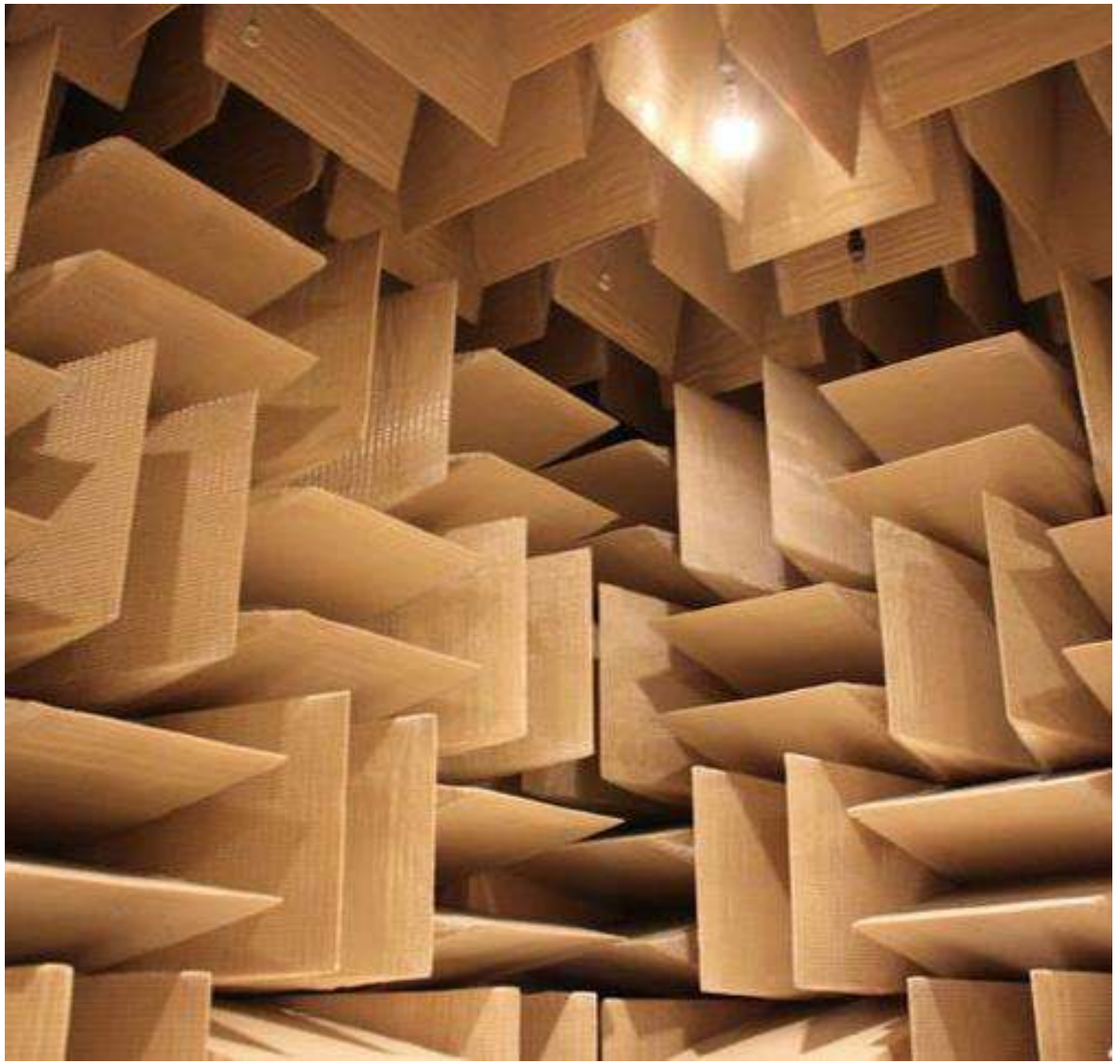
ABSORPTION

Acoustic absorption refers to the process by which a material, structure, or object takes in sound energy when sound waves are encountered, as opposed to reflecting the energy.

Part of the absorbed energy is transformed into energy (heat) and part is transmitted through the absorbing body.

An NRC of 1: prefect sound absorption.





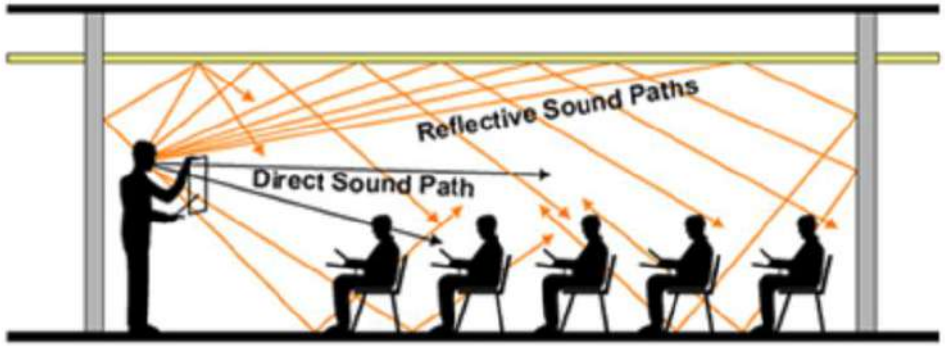
Credit: Radek Grzybowski

REFLECTION

Sound waves can be affected by the environment specially when striking a flat surface.

Materials and shape will vary the scattering of sound waves. Some porous materials will better absorb energy as to where some rough materials (relative to the wavelength) tend to reflect certain sounds.

An NRC of 0: prefect sound reflection.



SPEED

The speed of sound is the distance travelled per unit time by a sound wave as it propagates through an medium.

At 20 °C (68 °F), the speed of sound in air is about 343 meters per second (1,234.8 km/h; 1,125 ft/s; 767 mph; 667 kn), or a kilometre in 2.9 s or a mile in 4.7 s.

Credit: Eugene Triguba

REVERBERATION

Is the persistence of sound after sound is produced. It is created when a sound is reflected causing a large number of reflections to build up and then decay as the sound is absorbed by the surfaces of objects in the space.

This is most noticeable when the sound source stops but the reflections continue, decreasing in amplitude, until they reach zero amplitude.

Excess reverberation enchances noise.

Reverberation is not echo.

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REVERBERATION TIME

Is a measure of the time required for the sound to "fade away" in an enclosed area after the source of the sound has stopped.

Reverberation time is frequency dependant and is stated as a single value if measured as a wideband signal (20 Hz to 20 kHz).

Credit: Keagan Henman

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3. Quality of sound environment

1. ABCs of Acoustics
2. Sound Path Factors
3. Receiver Influences

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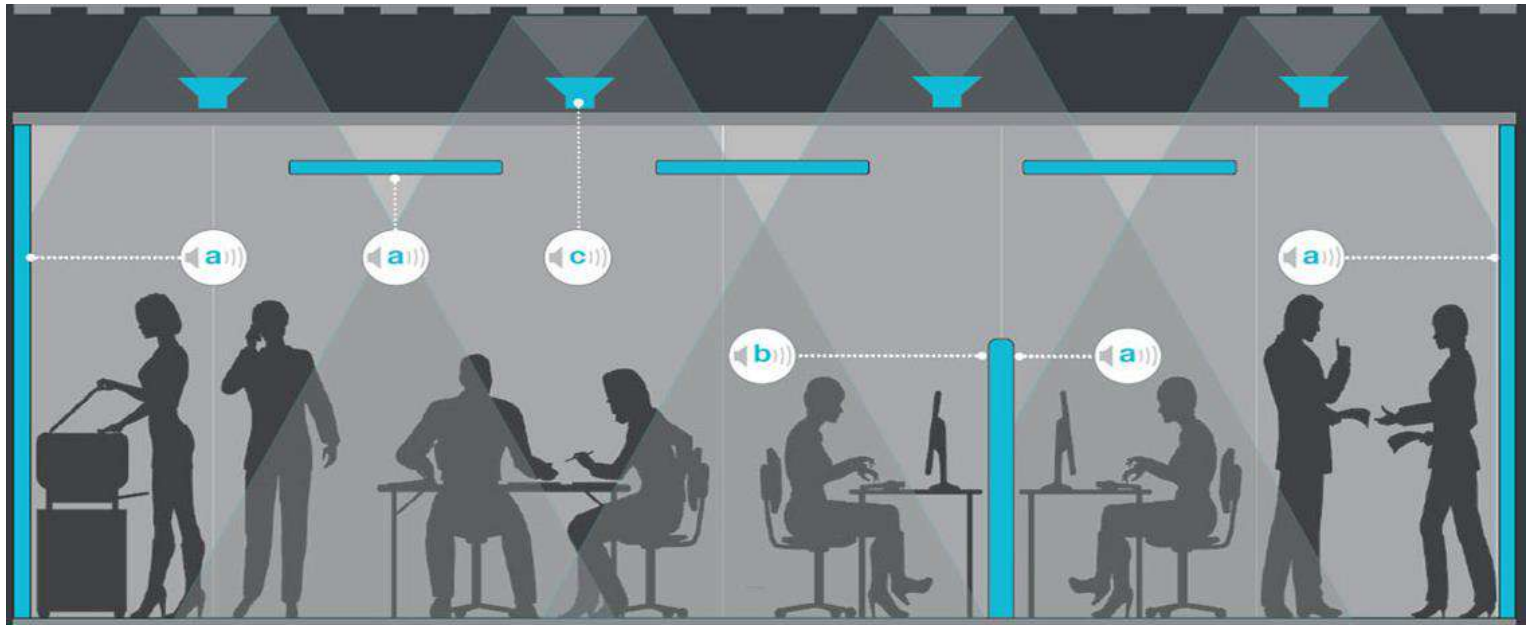
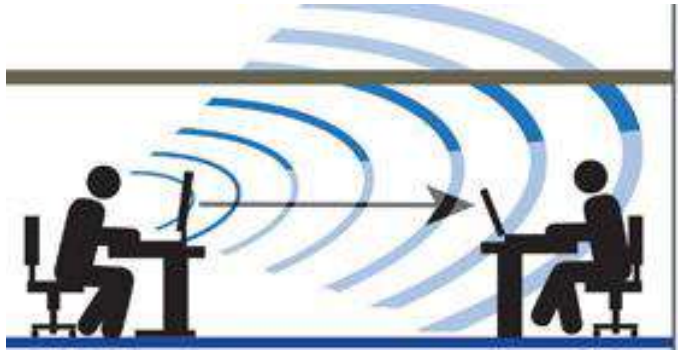
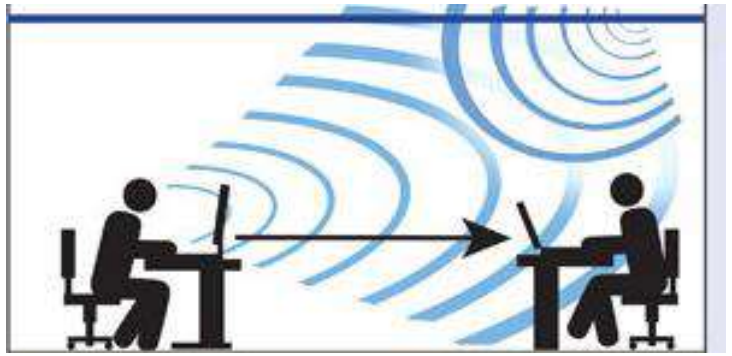


ABCs of Acoustics

- **Absorb** - Absorb sound energy & reduce reflection
- **Block** - sound barriers to prevent straight travel
- **Cover** - Ensure sufficient background sound levels





Credit: Acoustics by Design

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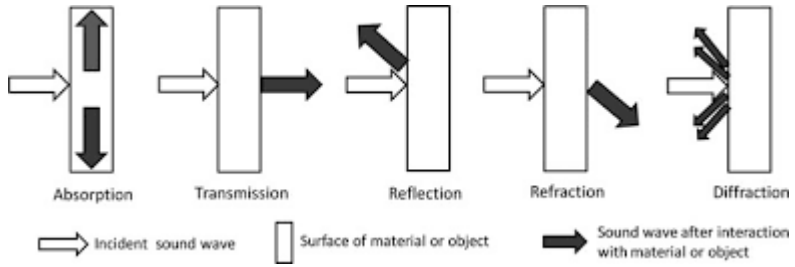
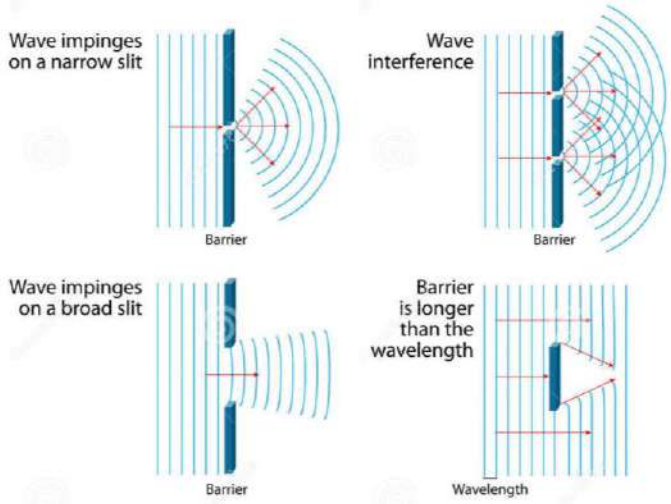
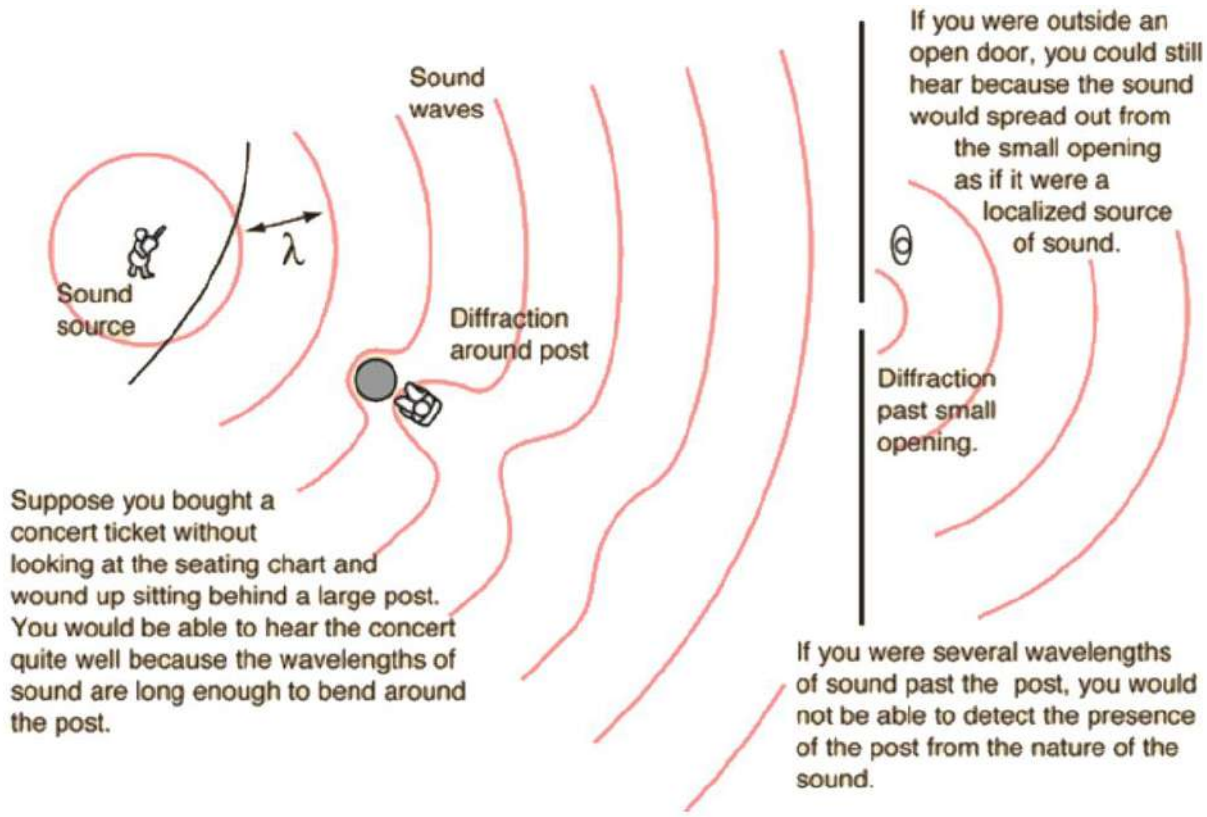
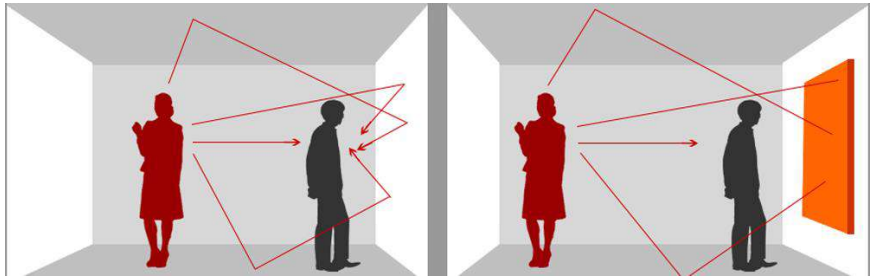
SOUND PATH FACTORS



DIFFRACTION OF WAVES







Credits: Comsol, Hyperphysics

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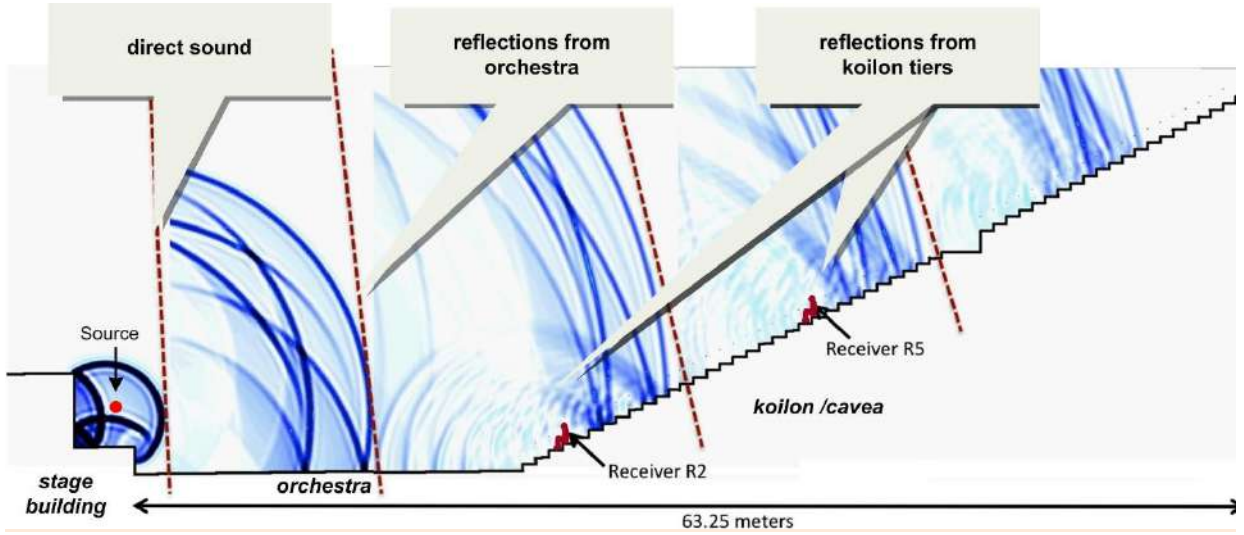
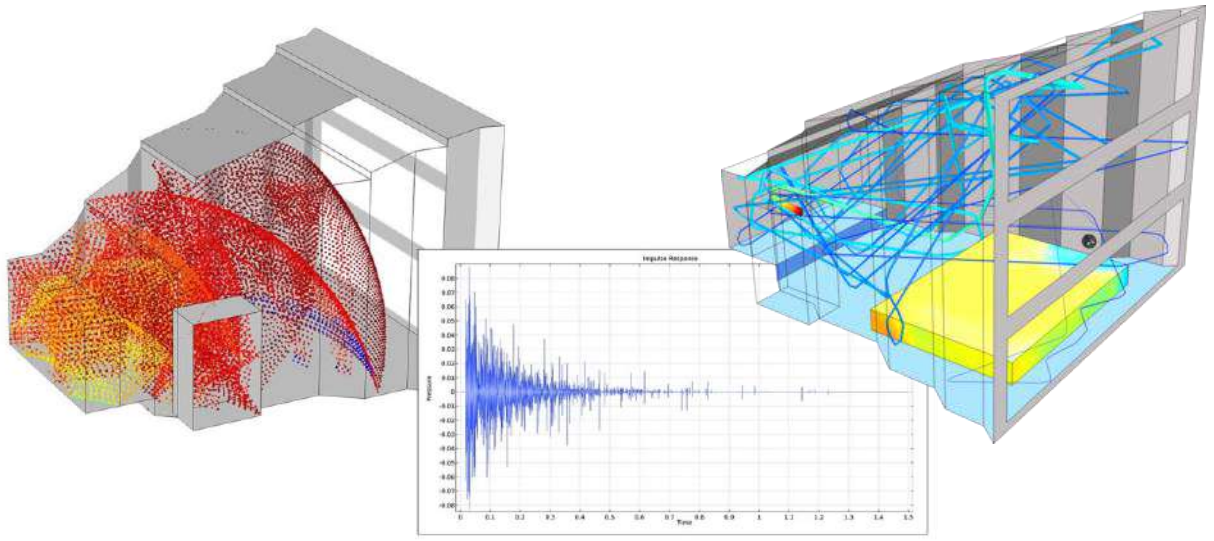
RECEIVER INFLUENCES

- Users
  - Age and hearing ability
  - Type of work
  - Increasing hearing loss
- Distance
  - Sound levels minimized over distance as energy is spread and diluted
- Reverberation time
  - Sound decay is faster with more sound absorbing material per volume





Credits: Comsol, Acoustics.org

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Credit: HBO Seattle

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4. Effective Integration of Acoustic Control in Lighting Fixture Designs

- Why Lighting Fixtures?
- Fixture Design vs. Fixture Layout
- Passive vs. Active Noise Control

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WHY LIGHTING FIXTURES?

- Out of visual field
  - Possible to have similar sound absorbing surface area compared to partitions
- Close to the ceiling
  - Traps sound between reflective ceiling and sound absorb materials
- Decorative elements
- Fabric materials

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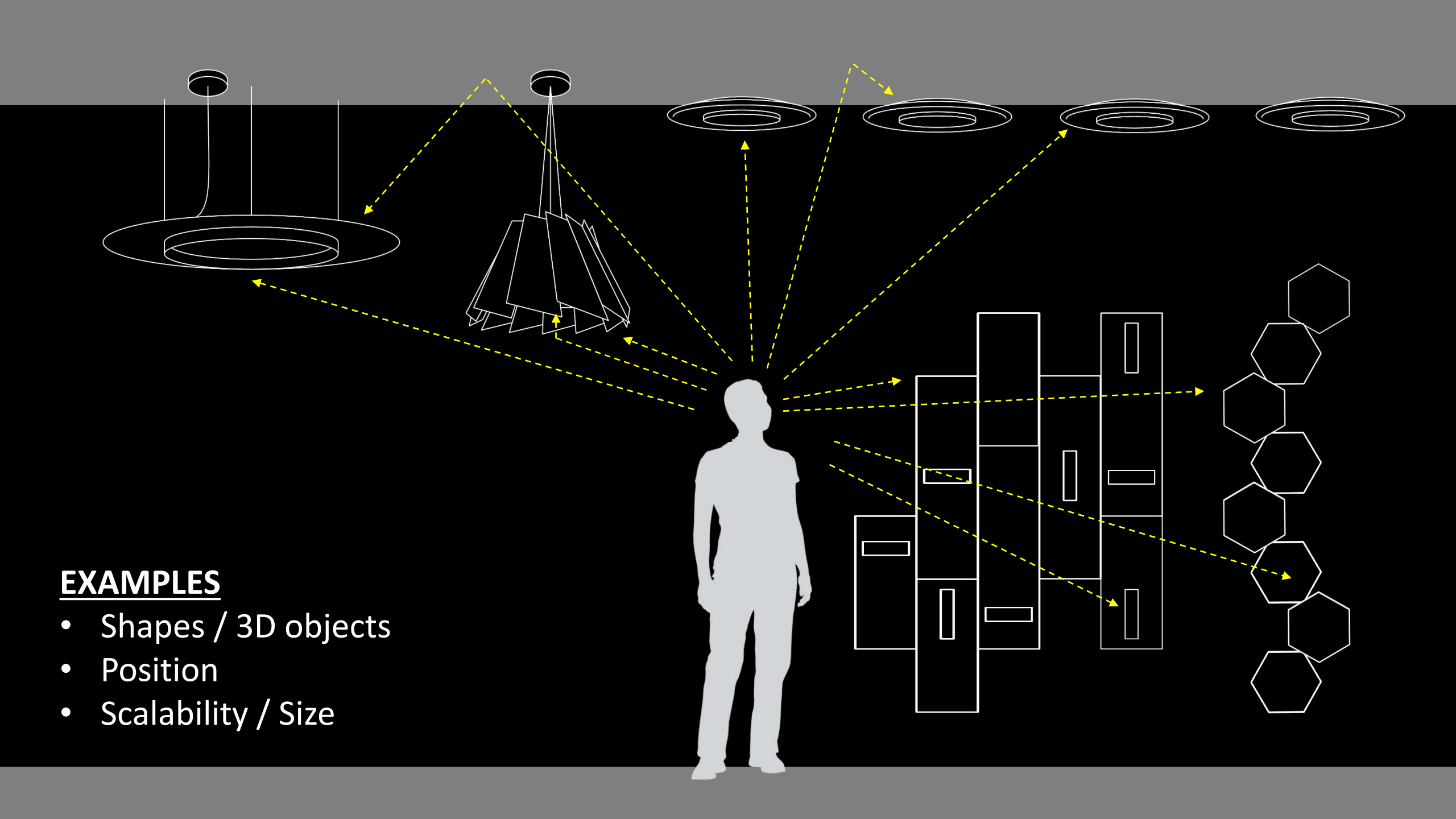
SOUND ABSORBING FIXTURE DESIGN

- Lighting first
  - Performance / spacing
- Material for sound absorbing
  - PET Recycled “Felt”
  - Fabric over perf metal
  - Foam
  - Wood & pulp




- Surface area
- 3D Designs
  - Multi-layer & Hollow
  - Sound trapping



EXAMPLES

- Shapes / 3D objects
- Position
- Scalability / Size

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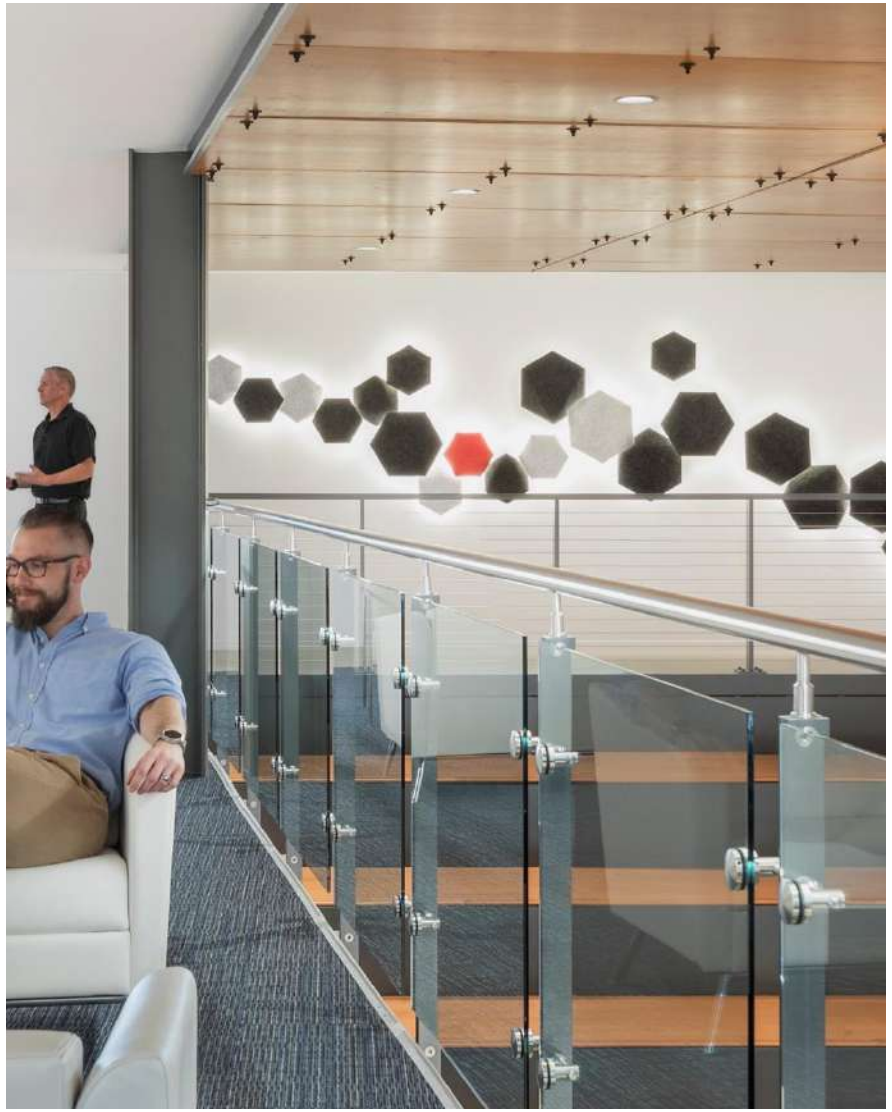

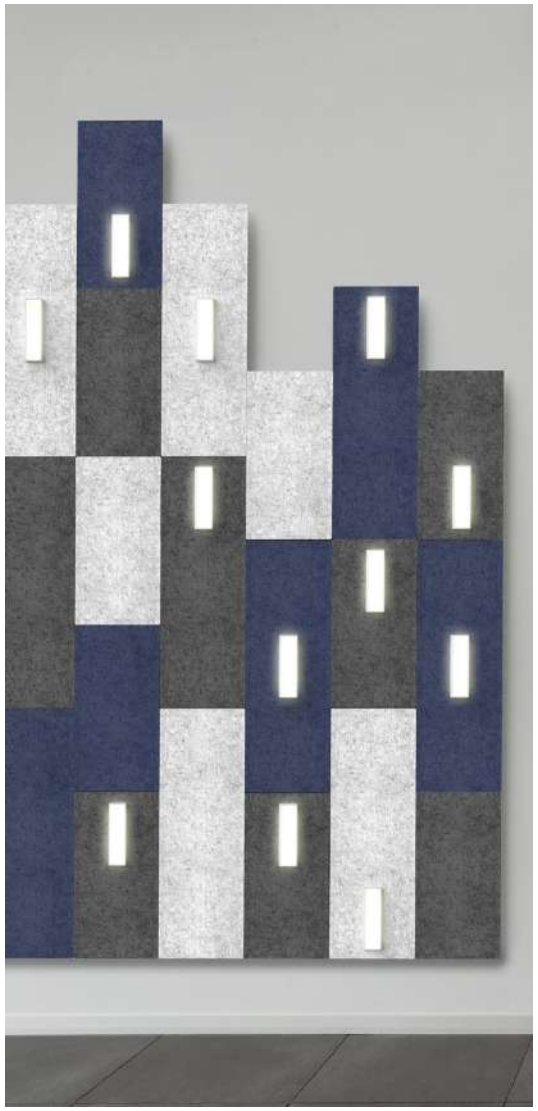

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ACTIVE SOUND MASKING

- Next horizon for lighting?
  - Integration in fixtures
  - Transducer system
- Cancelling vs Masking
- Sound level
  - Sound Masking cannot help too noisy
- Type of sound
  - White / Pink Noise
  - Spectrum required
- Zoning

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ACCREDITED LAB TESTING

- Measurement of sound absorption and absorption coefficients (ASTM C423-09a test) - NRC/SAA results
- Minimum surface area required
- Positionning and spacing is important

Credits: Riverbank Acoustical Laboratories

RECOMMENDED PRACTICES / TOOLS

- Consulting professionals (acousticians)
- Acoustic studies/analysis/simulations
- More surface area, better sound absorption
- NRC is good, but not it’s not all there is
- Spacing / density is important
- Good lighting can help sound control, but good sound absorption does not imply good lighting and vice-versa.

Credit: Bruce Mars

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This concludes The American Institute of Architects
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