INTELLIGENT PSYCHOACOUSTIC SPACES FOR HEALTH AND WELL-BEING

[innovation X]

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Knowledge on physiological reactivity to noise in virtual reality

Experimental results on responsive structures

Sensor-based measurements for quantifying physiological reactivity to noise

Objectives

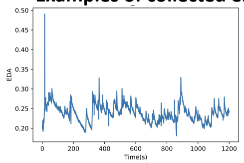
This component aims to quantify physiological reactivity to noise via:

1. analysing sweat and heart rate responses of participants conducting a set of cognitive tasks under three noise conditions
2. design machine learning algorithms to estimate participant stress and perceived cognitive demand using the physiological signals

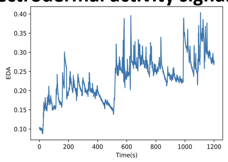
User studies: Methods

We are collecting neurophysiological data using wearable devices, including electrodermal activity (EDA), electrocardiogram (ECG), skin temperature, and blood volume pulse (BVP), from participants while completing cognitive tasks under three noise levels (highly intelligible background speech, poorly intelligible background speech, silence). Participants also filled out questionnaires for their feedback/perceived stress levels. So far we have collected data from 46 participants. We aim to recruit a total of 56 participants.

Examples of collected electrodermal activity signals



No Noise

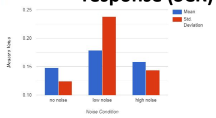


Low Noise

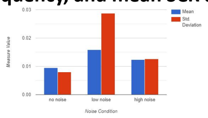
Data analysis and machine learning

We used statistical analysis to identify physiological differences across the three conditions. We will develop machine learning to estimate stress/ demand.

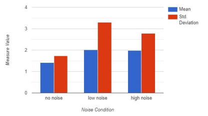
Mean and standard deviation of skin conductance level (SCL), skin conductance response (SCR) frequency, and mean SCR amplitude measures



SCR Mean



SCR Amplitude



SCR Frequency

Interaction between humans and adaptive responsive structures in virtual environments

Objectives

This component of the project proposes an immersive psychoacoustic design and evaluation workflow to:

1. test various acoustic materials while manipulating other environmental parameters
2. obtain instant user feedback under different acoustic environment.

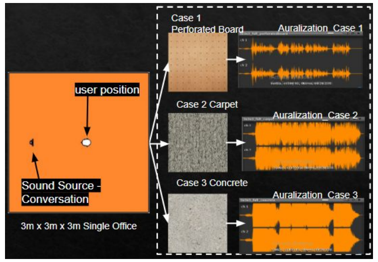


Figure 1. Auralization of a 3x3x3 office

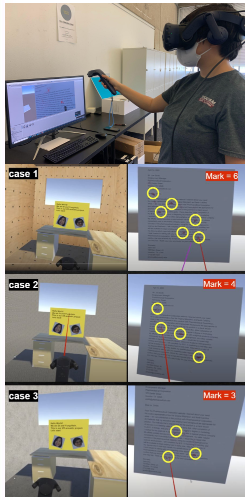


Figure 2. Psychoacoustic human test in virtual reality

Methodology and Experiment Design

The methodology includes two parts.

Part one includes the virtual acoustic scenario preparation (modeling and auralizing) and the human psychoacoustic test. In the human test, the participant performs a proof reading task under three acoustic conditions based on room material: perforated board, concrete, and carpet. Afterwards they evaluated their comfort in the different scenarios.

Part two is a validation study by using traditional acoustic simulation methods, specifically the Eyring equation.

Results

Participants had the highest score of task performance and subjective evaluation in the perforated board case. This is consistent with the results from Eyring equation, which shows that perforated board has the shortest reverberation time.

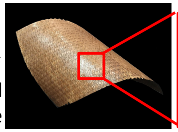
Adaptive responsive structures

Objectives

This component of the project explores tuning the room acoustics by changing the kerf density and geometrical shape of the MDF (Medium Density Fiberboard) Panel.

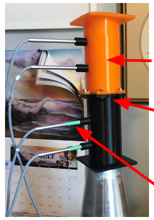
Absorption measurements

This research proposes a reconfigurable kerf Medium density Fiberboard (MDF) panel made up of unit cells as shown in the figure above. We collaborated with Bruel and Kjaer to measure normal incident absorptive properties of different kerf pattern unit cells using in-house 3-D printed impedance tube. It is evident from the results that altering the kerf pattern (LD – Low density, MD – Medium density, HD – High density) affected the absorption properties of MDF panels.



Kerf MDF Panel

hexagonal unit-cell



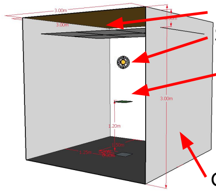
3D Printed impedance tube

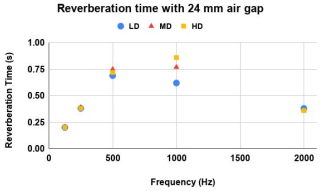
specimen

microphone

Ray tracing method to determine reverberation times

We modeled a closed office space with dimensions (3x3x3) meters, a sound source and a receiver. The ceiling of the room is covered with MDF kerf panels attached 24 mm away from the ceiling. The absorption results from impedance tube measurements are input into the ray tracing model. It can be concluded from simulations that LD kerf panel compared to other kerf panels reduces reverberation time which is suitable for a quiet office space. In addition to this, changing the gap size between the ceiling and kerf panels also effects reverberation time. Therefore, the results from these simulations can be used to design multi-purpose rooms with kerf panels to tune the room acoustics.





Knowledge on physiological reactivity to noise in real-life

Simulation results on responsive structures

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