Improving client understanding through auralisation of building element sound insulation

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ABSTRACT

Traditional acoustic reports often rely on decibel values and technical terminology, which many clients including architects, engineers, and building users find difficult to interpret. The Resonate AuralEyes project addresses this by developing a method for reproducing the sound insulation performance of partitions, doors, and glazing on headphones. The system allows clients to subjectively experience acoustic conditions through user calibrated audio files played over standard headphones, removing the need for specialist equipment or environments.

The core innovation is a calibration process using a reference recording of a human voice at one metre, which users adjust their playback volume to match. Subsequent audio files are scaled relative to this reference to maintain perceptual accuracy. The method was tested using various headphone models, validated through measurements and client feedback. Results indicate that the approach provides a sufficiently accurate and user-friendly representation of acoustic performance, improving client understanding and supporting more informed design decisions.

1 INTRODUCTION

In delivering acoustic consultation advice on architectural projects, there are inherent difficulties in understanding and interpreting acoustic terminology for the client, design team and stakeholders. Reliance is placed on the experience of the consultant or consultancy to effectively describe the subjective performance of a given metric, such as sound insulation, reverberation time and internal noise level, in order to inform the design decisions.

To accurately demonstrate the acoustic conditions of a space, specialist listening environments and calibrated sound reproduction systems are typically required. The limitations of this method of auralisation include:

- Expense in construction of an isolated critical listening room, with low noise floor, high level of sound insulation and low reverberation time
- Expense of reproduction equipment, including loudspeaker and signal processing systems
- Consultant time spent developing project specific auralisation scenarios that may not be relevant to other projects
- Travel time for client and stakeholders to experience the auralisation at a specific site and specific time
- Some listening rooms are calibrated so that only 1 person is able to position themselves at the ideal listening location at a time. Listeners surrounding that central spot may experience amplitude and phase distortions.

A method of allowing clients and other relevant stakeholders to make informed choices on architectural design decisions is desirable, particularly on lower value projects that cannot justify the expense of custom auralisations that may be expected during the design of more specialist spaces. Projects, such as the fitout of an office or development of a school, could benefit from a simplified approach to assist in informing design decisions and cost benefit analysis, without the expense associated with more detailed auralisations.

A method for the subjective comparison of the sound insulation performance for various lightweight partitions, glazing and doors is proposed. The use of headphones for sound reproduction for the listener is proposed to avoid some of the difficulties associated with auralisation in a specialist acoustic space. As is noted in Beresford and Wong (2021):

> *The use of headphones as the audio playback medium for auralisations has many advantages over the more typical "listening room" setup utilising multi-channel loudspeakers in an acoustically dead and quiet room.*

The intent of this experiment is to assess whether the measurement and reproduction of the sound insulation performance of building elements over headphones provides enough accuracy to inform stakeholder decision making in the design of typical office and school developments.

2 METHOD

2.1 Initial auralisations

The transmission loss of partition constructions were predicted for sound insulation ratings in 5 dB increments between R_W 40 and R_W 70 using INSUL v10. The partition constructions are detailed in Table 1.

Table 1: Lightweight partition constructions modelled

Partition R_W rating	Partition construction
40	• 64 mm steel studs, 0.55 BMT @ 600 mm centres • 1x13 mm standard plasterboard to both sides (8.5 kg/m^2) • 50 mm, 14 kg/m^3 polyester insulation in the partition cavity
45	• 92 mm steel studs, 0.55 BMT @ 600 mm centres • 1x13 mm sound rated plasterboard to both sides (13 kg/m^2) • 50 mm, 14 kg/m^3 polyester insulation in the partition cavity
50	• 92 mm steel studs, 0.55 BMT @ 600 mm centres • 1x13 mm sound rated plasterboard on one side (13 kg/m^2) • 2x13 mm sound rated plasterboard to other side (26 kg/m^2) • 50 mm, 14 kg/m^3 polyester insulation in the partition cavity
55	• Staggered steel stud in 92 mm track • 2x13 mm fire rated plasterboard to both sides (21 kg/m^2) • 50 mm, 14 kg/m^3 polyester insulation in the partition cavity
60	• Double stud wall, 148 mm cavity • 2x13 mm sound rated plasterboard to both sides (26 kg/m^2) • 2x50 mm, 14 kg/m^3 polyester insulation in the partition cavity
65	• Double stud wall, 200 mm cavity • 2x13 mm sound rated plasterboard to one side (26 kg/m^2) • 3x13 mm sound rated plasterboard to other side (39 kg/m^2) • 2x50 mm, 14 kg/m^3 polyester insulation in the partition cavity
70	• Double stud wall, 300 mm cavity • 3x13 mm sound rated plasterboard to both sides (39 kg/m^2) • 2x50 mm, 14 kg/m^3 polyester insulation in the partition cavity

Transmission loss data for three typical glazing types and three door types were also used:

- R_W 36 glazing (10.38 mm laminated glass)
- R_W 40 glazing (12.5 mm VLam Hush glass)
- R_W 48 glazing (6.38 mm laminated glass / 100 mm air gap / 10.38 mm laminated glass)
- R_W 30 door
- R_W 35 door
- R_W 40 door.

The one-third-octave transmission loss values for each of the elements were recreated in a Digital Audio Work-station (DAW) using a series of parametric equalisers.

Typical sound sources for offices and schools were identified. Sound sources selected for the auralisations were:

- General office ambience (multiple voices)

- Piano
- Drums
- Bass guitar.

The equalisation filters for the different construction elements were applied to the source audio files. The gain structure was maintained for all sources. This allowed for the relative level difference of the different partitions to be subjectively assessed in a side-by-side comparison.

Whilst the relative comparison between elements proved useful, the absolute level of the reproduced audio led to some confusion around the audibility of the sources that would be experienced in the actual room. A way to 'calibrate' the audio files therefore required further investigation.

2.2 Use of reference audio

Use of a reference audio file that would allow the user to adjust the volume of their headphones to an appropriate level was proposed. A voice at 1 metre was suggested as a suitable reference source. This would enable a listener in any location, using any headphones, to manually adjust the gain of their headphones and 'calibrate' their system to an approximate level that would be accurate enough to assist in the subjective assessment of the construction elements and provide an indication of the absolute level that would be achieved.

This introduced a complication, however, as whilst predicting the sound pressure level of a given source in the receiver room was possible based on the proposed construction element, how this related to the reference recording sound level in the DAW was not fully understood, and the produced auralisations did not seem subjectively realistic.

2.3 Reference audio testing

To examine the correlation between the sound pressure levels measured in a room with the sound levels in the DAW, the following testing was proposed and undertaken.

The sound insulation performance of a typical office partition was measured in accordance with AS ISO 140.4 *Acoustics - Measurement of sound insulation in buildings and of building elements, Part 4: Field measurements of airborne sound insulation between rooms*. This was to establish a baseline sound insulation performance of a known element to verify the relative levels between source and receive room levels.

Within the receiver room an NTi Audio TalkBox was set up playing a recording of the reference voice. This was measured with a NTi XL3 sound level meter at a distance of 1 metre from the TalkBox to give a reference level of L_{Aeq} 60 dB. A recording of the TalkBox at 1 metre was also taken using the DAW using an NTi MA220 1/2-inch omni-directional free-field microphone. The gain of the microphone was adjusted to provide enough headroom for the recording of the various noise sources within the receive room without clipping. This gain level was then fixed for the remainder of the recordings.

The various sound sources were then replayed in the source room via a loudspeaker. The source level was adjusted to the following levels:

- General office ambience (multiple voices) – L_{Aeq} 80 dB
- Piano – L_{Aeq} 80 dB
- Drums – L_{Aeq} 93 dB
- Bass guitar – L_{Aeq} 90 dB.

The sound pressure level of each source in both the source and receiver room was measured, and the receiver room sound was recorded into the DAW, both with and without the reference voice from the TalkBox.

Having quantified the sound insulation performance of the separating partition, comparison of the level difference between the recorded reference voice level (L_{Aeq} 60 dB), and the source level recorded by the DAW in the receiver room, for a known sound pressure level and sound insulation performance was undertaken. The predicted composite R_W performance of the tested partition was then created as an equalisation filter and the levels of the sources and reference voice were adjusted until they were judged to be similar to what was recorded.

The auralisations were then created, using the same reference voice recording to allow the user to adjust the volume level. The equalisation and gain level of the sound sources was adjusted relative to the reference voice, based on the test recordings and measurements of the known element. The equalisation filters based on the predicted transmission loss values for each of the construction elements were then applied to the source audio files to allow for subjective assessment relative to the reference voice level.

3 RESULTS

The audio files can be found on Resonate's website here.

Results subjectively demonstrated better alignment with the actual sound levels experienced during the testing of the known separating element alongside the reference audio, and this was then aligned with the predicted performance of the various construction elements to more faithfully recreate what would be experienced in real life.

Initial feedback from clients and stakeholders has been positive. Further feedback will be gathered as more clients are provided with the auralisations to assess the usefulness of this resource on future projects.

4 CONCLUSIONS

Allowing the listener to adjust the audio volume themselves, based on a sound source that is familiar, offers the following advantages:

- Improved accessibility – available to any client or stakeholder, in any quiet environment where they have access to the internet and headphones
- Cost effective – generalised spaces and sound sources allow for subjective assessment without the need for project-specific modelling
- Scalable – different sound sources and construction elements can be modelled and processed in the same way to expand the existing selection of files easily.

Inherent limitations using the above approach are also noted:

- Inaccurate perception – use of headphones is not representative of listening conditions experienced in actual rooms. However, reproduction through loudspeakers would also affect the accuracy of the simulation due to room effects and ambient noise levels in the listening environment.
- Controlled listening conditions – the fidelity of the playback system and listening environment may affect the user experience. Auralisations can only be as good as the playback system used to reproduce them. The quality and accuracy of the playback system can significantly affect the perceived realism of the auralisation. For example, there would be significant differences between listeners using open or closed back headphones, and in ear monitors. However, if the listener uses the same headphones throughout, comparison of the construction elements would still provide a meaningful comparison.
- The use of headphones with active noise cancelling (ANC) technology can affect the perception of the auralisation stimuli as ANC technology can 'add other types of noise and distortion both in the frequency and time domains' Temme, (2025:8).
- High background noise levels in the environment may mask the changes between auralisation files, even when listening with headphones.

A disclaimer ensures users are aware of limitations and that auralisations are a supplementary tool, not a replacement for formal assessment.

Providing a reference sound that is familiar to the listener and allowing them to adjust the listening level accordingly assists in providing confidence in the auralisation and provides a more accurate representation of how the sound levels will actually be perceived.

The method provides a cost-effective means for clients to experience sound insulation differences without requiring specialist facilities.

Further work that is intended to be undertaken:

- Gather more extensive feedback from clients and stakeholders to further improve the resource
- Binaural post processing to create more realistic reproduction over headphones
- Extended sample of construction elements and sound sources
- Impact sound insulation measurements and recordings to compare flooring systems.

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