Auralisation vs reality: A study of the plausibility of auralisations using AiHear®

Tim Beresford (1), Hannah Hill-Marks (2) and Sophia Axenova (2)

(1) NDY Acoustics, Auckland, New Zealand
(2) Department of Mechanical and Mechatronics Engineering, The University of Auckland, Auckland, New Zealand

ABSTRACT
Auralisation is a method of simulating real or hypothetical auditory environments as accurately as practicable. This study evaluates the plausibility of audio samples generated by the AiHear auralisation engine compared to binaural recordings captured in real rooms. AiHear is an auralisation tool created by NDY, which utilises the processing power of consumer-grade devices to make auralisations portable and accessible across a wide range of acoustic engineering applications.
The study's experimental design involved capturing audio recordings of speech and music samples from physical rooms using a head-and-torso simulator and generating corresponding simulations within the AiHear system. A survey of 30 participants was conducted, involving subjective listening tests to determine whether participants could reliably distinguish between recorded and simulated audio samples by assessing the plausibility of each. A second part of the study assessed the survey participants' impressions of the similarities, differences, and preferences towards real-room audio recordings compared to those modelled using the AiHear app. During the study, a recorded video of a real room was included to help listeners feel immersed and better assess the plausibility of the auralisations.
Results showed that participants generally struggled to correctly identify the AiHear simulations, although some differences were perceived between the simulated and real-room recordings. The study highlights that while exact replication of real acoustic environments is challenging, AiHear auralisations can achieve a level of plausibility that makes them difficult to distinguish from reality, supporting the use of the AiHear app as a valuable tool for auralising auditory environments.

1 INTRODUCTION

The advancement of virtual and augmented reality technologies has significantly expanded the capability to simulate environments, moving beyond visual immersion to include realistic auditory experiences. Auralisation, the process of simulating acoustic environments with technical accuracy, enables the creation of various soundscapes without the need for them to be physically constructed. This approach is particularly relevant in architectural acoustics, where designers require tools to communicate various acoustic parameters effectively between themselves and to clients who are not always well versed in the field of acoustics (Beresford and Wong, 2023). The significance of this work is underscored by the growing use of virtual reality applications in diverse fields, including architecture, education, rehabilitation, and exposure therapy (Diemer and Zwanzger, 2019), where realistic auditory environments contribute to immersive and effective experiences.

This study investigated the plausibility of audio samples generated using the AiHear auralisation engine, developed in-house by NDY. AiHear has been designed to be a user-friendly, portable and accessible tool capable of producing engineering precision auralisations using consumer-grade technology.

The research aimed to evaluate perceptual differences between auralised audio samples and physically recorded audio in real rooms, assessing how closely the simulations could approximate reality. By focusing on plausibility as the evaluation criterion – defined as the degree to which the simulated auditory experience aligned with the listener's internal perception of reality – this research sought to verify the modelling simplifications made within the AiHear engine that enable it to run in real-time on a portable device. Through subjective evaluation involving human participants, this project aimed to determine whether the AiHear engine could deliver plausible audio simulations for participants.

This paper is the culmination of two final-year Bachelor of Engineering research projects conducted collaboratively in 2024 by students Hannah Hill-Marks and Sophia Axenova. NDY was the project sponsor, with Tim Beresford acting as the technical advisor on AiHear.

2 LITERATURE REVIEW

A key theme that emerged in the literature surrounding auralisation research was the challenge of evaluating perceptual realism in a consistent and subjective manner. Various studies employed terms such as "plausibility", "realism", and "authenticity" to describe listener perceptions of simulated acoustic environments. However, these terms were often used interchangeably, despite reflecting different underlying concepts. This lack of terminological precision posed a barrier to cross-study comparability and the development of standardised evaluation protocols.

Plausibility emerged as a particularly useful criterion, as it reflected the listener's judgment of whether a simulated sound environment aligned with their expectations based on prior experience. Slater (2009) described plausibility as the perceived credibility of a scenario, noting that a simulation did not need to be flawless or indistinguishable from reality; rather, it needed to align sufficiently with the listener's mental model of what that environment should sound like. Lindau's (2011) framework further refined this concept by distinguishing between internal and external plausibility. The latter – a focus in this project – depended on general real-world experiences rather than precise internal references.

Hofer et al. (2022), and Busselle and Greenburg (2000) argued that plausibility judgments functioned as probabilistic assessments in situations where participants lacked direct experience with the acoustic context being simulated. For example, Bresciani's (2024) study on wind turbines illustrated that unfamiliarity made it difficult for listeners to rate plausibility meaningfully. These findings highlighted the influence of contextual cues and prior exposure on perceptual judgment, supporting the use of visual representations or familiar audio content to anchor listener expectations.

Overall, the literature indicated a strong need for greater standardisation in auralisation testing methodology. The inconsistent use of terminology, differences in participant familiarity, and variation in listening context reduced the reliability of subjective evaluations. This study aimed to address these gaps by focusing specifically on plausibility, using controlled audio-visual scenes to assess how closely simulated environments could replicate real-world acoustic experiences.

3 EXPERIMENTAL METHODOLOGY

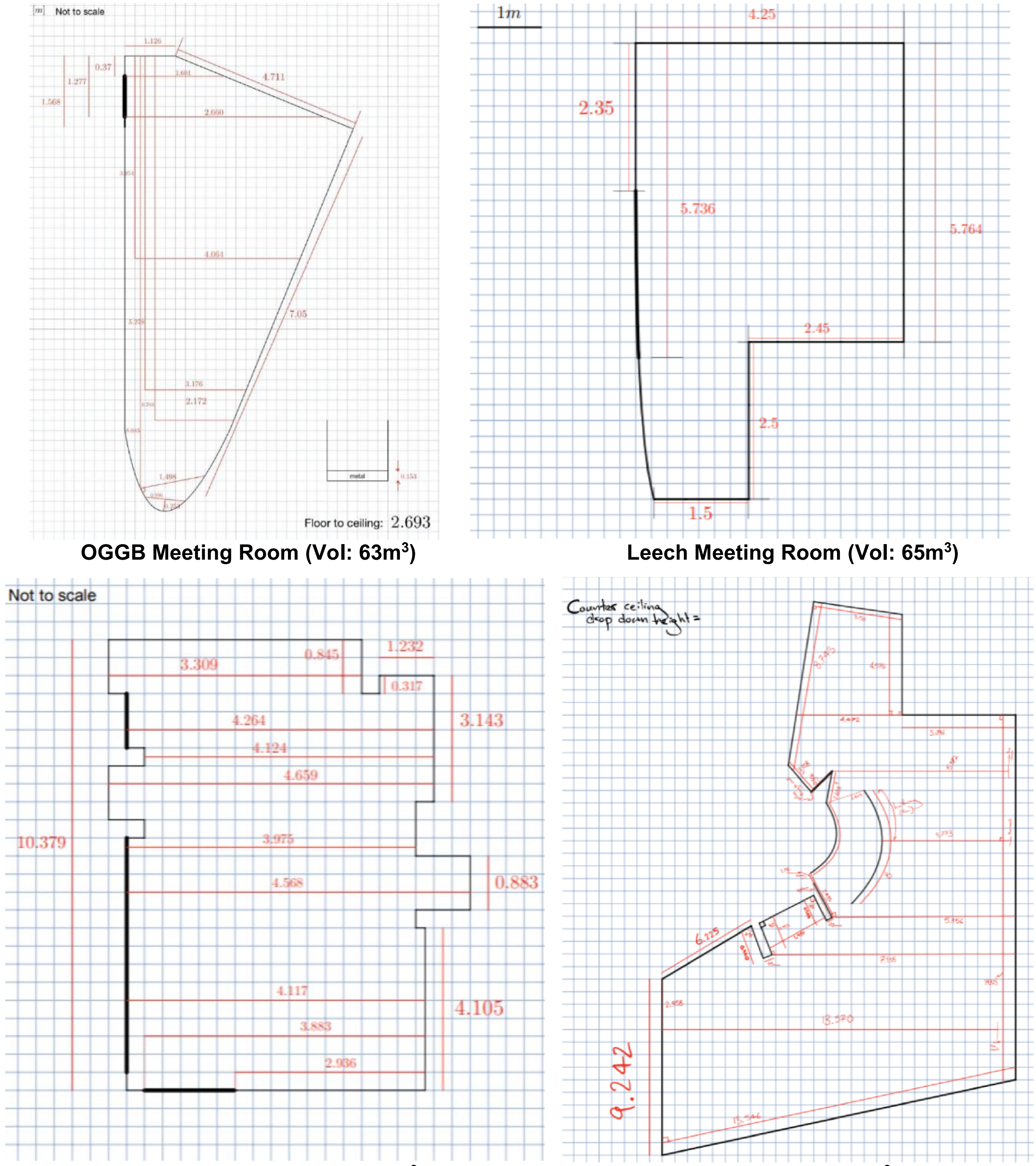
This section outlines the methodology used to investigate the perceptual differences between real and simulated acoustic environments. The study was based on a comparative evaluation of binaural recordings captured in real rooms and corresponding auralisations generated using the AiHear simulation engine. A combination of controlled field recordings, digital signal processing, user testing, and statistical analysis was employed to assess audio plausibility across a range of spatial contexts.

3.1 Study Objectives

The primary objective was to determine how plausibly AiHear could reproduce the acoustics of real environments familiar in everyday life. A secondary aim was to examine how factors such as source-to-receiver distance, room geometry, receiver movement (stationary vs rotating), and background noise influenced listener perception of plausibility and audible differences.

3.2 Space Selection and Room Modelling

Four different rooms were selected from the University of Auckland City Campus to provide a variety of spatial conditions: OGGB Meeting Room, Leech Meeting Room, 1202 Meeting Room and Strata Cafe. These rooms ranged in shape and size and were chosen to reflect differences in geometry, reverberation times (RT), and background noise profiles. All rooms selected had level floors, orthogonal walls, and ceilings parallel to the floor, in compliance with AiHear's modelling constraints.



OGGB Meeting Room (Vol: 63m³)

Leech Meeting Room (Vol: 65m³)

1202 Meeting Room (Vol: 110m³)

Strata Cafe (Vol: 630m³)

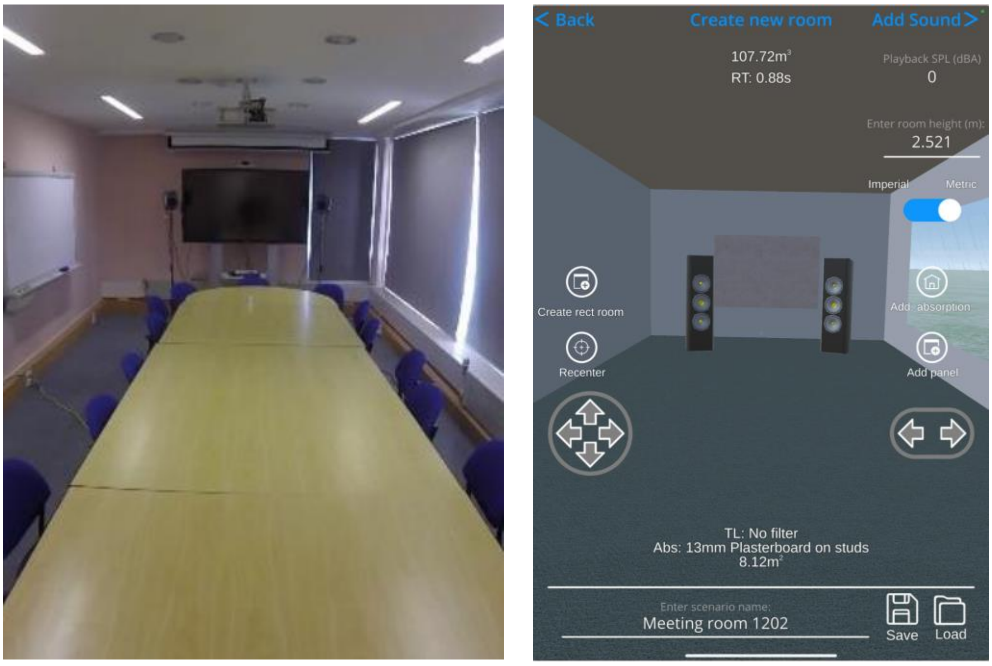
Figure 1: Plan view of rooms selected for plausibility study

RT values were measured for all rooms in accordance with ISO 3382-2 (2008) engineering method, with more positions being used for Strata to account for its complicated geometry.

Table 1: Measured RT in rooms selected for plausibility study

Room	OGGB	Leech	1202	Strata
Average RT (s), 125-4000Hz	0.76	1.06	0.68	0.80

Room models were then recreated within the AiHear platform. In cases where finer geometric features (e.g., furniture or shelving) did not significantly influence the RT, they were omitted for simplification.



Physical room **AiHear simulated room**

Source (Axenova and Hill-Marks, 2024)
Figure 2: 1202 Meeting Room - physical vs AiHear simulated room

3.3 Audio Recording Process

Binaural recordings were taken using the GRAS 45BC KEMAR Head and Torso Simulator (HATS), designed to simulate an average adult head and ear canal response. The HATS was mounted on a rotation-controlled turntable and positioned with the top of the head at a height of 1650 mm above the floor (approximate height of an average New Zealand woman). Two Genelec 8020D loudspeakers were placed on stands at a consistent height of 1700 mm to the top of the speakers.

Recordings were made with the HATS, both stationary (facing directly forwards), and rotating through an angle of 90° and back in 10 seconds (facing left to right to left) during playback, replicating head movement relative to the stationary sound sources. Two distances between the sound sources and binaural receiver were used in each room, labelled "Near" and "Far".

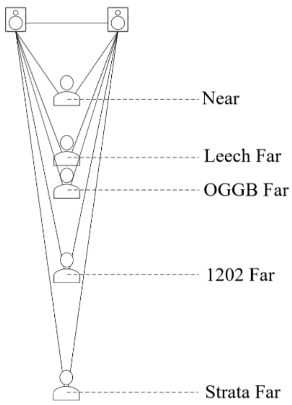


Figure 3: Relative distances of the HATS to loudspeakers

Near: Equilateral triangle with 1700 mm between the loudspeakers and from loudspeakers to the HATS (the same "Near" geometry was used for all rooms)

Far: Distance from the HATS to each loudspeaker approximately two-thirds of the room’s long dimension: Leech room: 3330mm, OGGB room: 4000mm, 1202 room: 6000mm, Strata Cafe: 8800mm

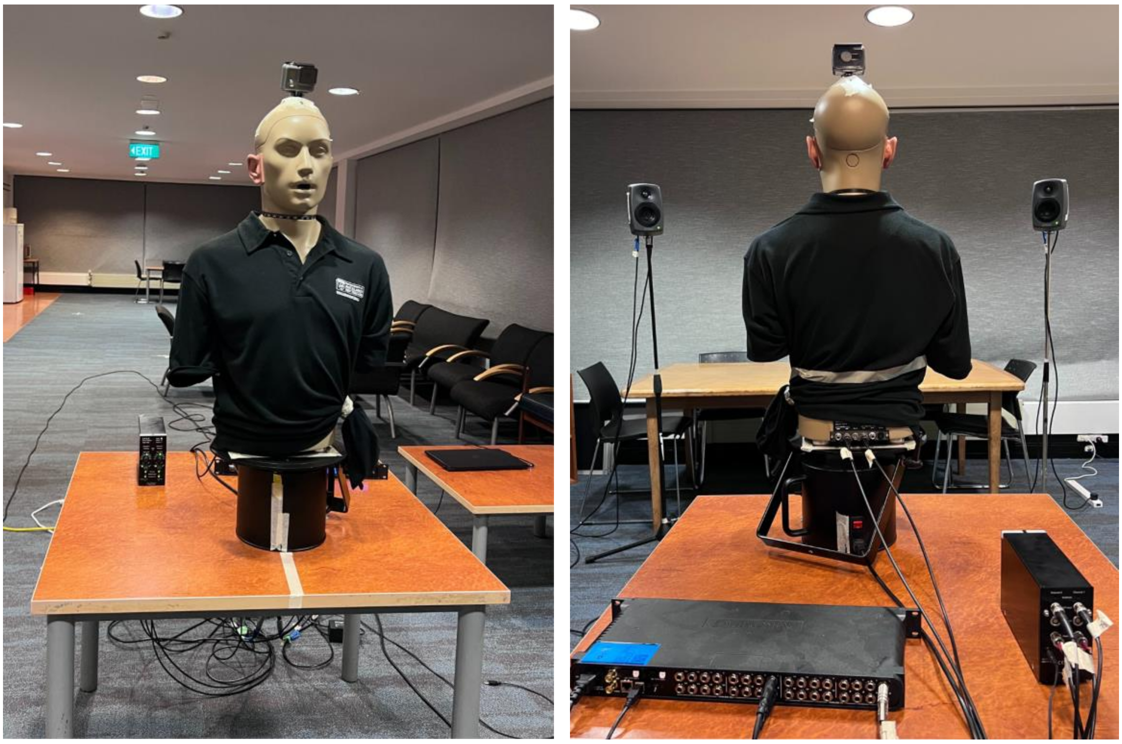
Familiar “real-life” audio content was chosen for the study to align with the functional purpose of the AiHear app. Speech (male/female dialogue) and music (a jazz fusion excerpt) were used as stimuli.

Speech content consisted of semantically unpredictable sentences (Grice and Hazan, 1996) presented as stereo tracks – one voice per loudspeaker channel – to simulate a conversation between two people. Drawing from lists of monosyllabic, phonemically balanced words, five sentences were developed, one for each structure. The order of the sentences was revised to mimic natural conversational flow, with the final speech sample script as follows:

- Male (left channel): “An old page copies the fence. Never close a tree.”
- Female (right channel): “When does a house paint the dark plain?”
- Male (left channel): “Often peel the table and the hat.”
- Female (right channel): “Scolded well in thin pearl.”

The music excerpt was selected for its energetic aesthetic and strong stereo image. In particular, the percussion of the original stereo music track was panned hard left and right, and there was a distinct difference between the output from the left and right loudspeakers.

Room-specific background noise was recorded using a UMIK-1 omnidirectional microphone and later matched to the final audio samples by extracting 10-second background clips based on temporal consistency. In AiHear, these noise recordings were overlaid using the “Background Noise” feature to simulate the real rooms’ background noise environment. For the three meeting rooms, the background noise was added as a reverberated stereo signal with no specific spatial location in the AiHear model. In the case of Strata Cafe, the background noise was heavily dominated by a large fridge that was located behind the counter, so this noise source was spatially placed in the AiHear model for this room.



Source (Axenova and Hill-Marks, 2024)
Figure 4: Binaural audio recording equipment setup

3.4 Video Recordings

Video recordings of the physical rooms were captured using a GoPro camera from a viewpoint on top of the HATS (as close to eye level as possible), with the HATS in both the stationary and rotating configurations.

3.5 Auralising in AiHear

The loudspeaker positions, receiver locations, head orientations and head movements employed in the physical room recordings were modelled in AiHear. The raw audio samples reproduced through loudspeakers in the physical rooms were also played through the simulated loudspeakers in AiHear. The balance between the sound source and background noise levels was adjusted in AiHear to match those found in the physical room as closely as possible. AiHear's algorithms were then used to render spatial stereo audio files for each test scenario based on the room geometry and sound absorbing materials present. The gain of the auralised audio files was adjusted to match those from the physical room recordings.

3.6 Audio Recording Post Processing

Post-processing of the physical room audio recordings was necessary to correct for frequency response inconsistencies. Corrections were performed in Audacity® using the basic gain and graphic equaliser plugin, as outlined below.

3.6.1 HATS Ear Canal Correction

The binaural recordings were taken using a HATS manikin fitted with ear canal simulators. These ear canals exhibit a particular resonant response which is intended to replicate that of a typical human ear. The manufacturer-published corrections for this resonance (GRAS, 2020), but when applied, these were found to sound very unnatural. Alternative corrections were derived based on measurements of sound reproduced in a semi-anechoic room (the University of Auckland's listening room) and measured with the HATS binaural microphones to better represent the typical configuration for which AiHear would be used. One-third octave corrections were determined and added to the physical room recorded audio tracks.

Table 2: HATS 1/3 octave-band frequency response corrections

Freq. (Hz)	Corr. (dB)	Freq. (Hz)	Corr. (dB)	Freq. (Hz)	Corr. (dB)	Freq. (Hz)	Corr. (dB)
25	-1	160	0	1000	-5	6300	-8
31	-1	200	0	1250	-6	8000	-3
40	0	250	0	1600	-7	10000	1
50	0	315	-1	2000	-14	12500	-4
63	0	400	-1	2500	-18	16000	-4
80	0	500	-2	3150	-17	20000	-3
100	0	630	-2	4000	-16		
125	0	800	-4	5000	-13		

3.6.2 Loudspeaker Frequency Response Correction

A further correction was applied to account for the non-flat frequency response of the Genelec 8020D loudspeakers, which was determined through measurement and applied to the physical room recordings. Again, the one-third octave corrections were added to the recorded audio tracks.

Table 3: Loudspeaker 1/3 octave band frequency response corrections

Freq. (Hz)	Corr. (dB)	Freq. (Hz)	Corr. (dB)	Freq. (Hz)	Corr. (dB)	Freq. (Hz)	Corr. (dB)
25	8	160	-5	1000	-2	6300	3
31	0	200	3	1250	-1	8000	5
40	-4	250	6	1600	1	10000	2
50	-7	315	-1	2000	-1	12500	4
63	-11	400	1	2500	-4	16000	2
80	-3	500	-1	3150	-3	20000	-2
100	0	630	0	4000	-2		
125	-1	800	-2	5000	-1		

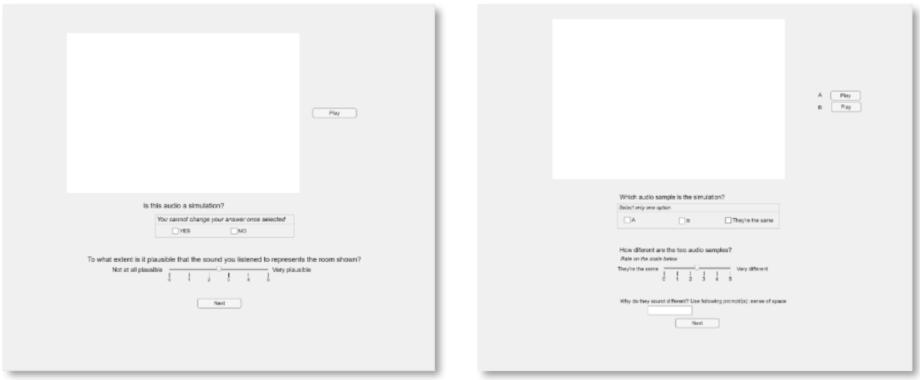
With these corrections applied, the spectral balance between the physical room recordings and the AiHear-generated audio tracks was generally subjectively very similar.

4 SUBJECTIVE EVALUATION

This section details the design and protocol for the subjective testing of participants. An ethics application was submitted to the University of Auckland, for the use of human participants, and approval was granted on the 11/09/24. Participant were given a gift voucher of nominal value as appreciation for their time.

4.1 Test Environment

The listening test user interface was constructed in Matlab App Designer. The visual interface was built using the component library, and the interactions and callbacks written into the manual coding function. The layout of the user interface for the main sections of the test is a per the figures below.



Source (Axenova and Hill-Marks, 2024)
Figure 5: Subjective test user interface

The tests were conducted in a quiet listening room (measured background noise level of 29dB L_{Aeq}), in the University of Auckland Acoustics Building. Subjects were seated at a desk with a computer monitor placed at eye level and could navigate the tests using a standard keyboard and mouse setup. Sennheiser HD800S high definition, open backed headphones were used for all participants.

4.2 Participants

A total of 30 participants took part in the research. The requirements outlined in the recruitment flyer were to be aged between 18 and 55 years old, have no reported hearing impairment and have comprehensive English skills. Participants were also asked if they have a background in acoustics in order to see if that affected the responses in any way. Out of the 30 participants, 18 were male, 11 female and 1 gender diverse. 20 of the participants were aged 18-23 years old, 6 were aged 24-30 years old, 2 were aged 30-40 years old and 2 were aged 50-55 years old. Five of the participants stated they had a background in acoustics.

4.3 Pool of Audio Test Samples

In each of the 4 selected rooms, 8 real recordings were taken, as well as 8 auralisations. In total, 64 unique audio stimuli were created, all of which were cut to be 10 seconds in length. In each room, 4 video recordings were taken (stationary vs. rotating, near vs. far) and combined with the corresponding audio stimuli. To avoid visual cues adding bias to the tests for this audio study, all audio stimuli (whether from real rooms or AiHear-generated) were combined with the video clips taken from the real rooms.

4.4 Test Procedure

Initially, participants were given simple training exercises to familiarise themselves with the test environment.

For the first section of the test (Section 1), participants were played a single video and audio stimuli combination and asked to identify whether they thought the audio component was an AiHear simulation: "Is this audio a simulation?", resulting in a YES/NO forced-choice answer. A justification text box was provided for participants to optionally explain their choice. Participants were then asked to rate the plausibility of the audio sample on a continuous scale ranging from 0 "Not at all Plausible" to 5 "Very Plausible". Users could then click to navigate to the next audiovisual sample. There were no replays of the samples for this section but there was unlimited time for answering.

For Section 2 of the test, participants were presented with two samples, resulting in a hidden real reference discrimination test. The visual recording was identical for both audio samples presented. Two buttons (A/B) were displayed on the screen which, when pushed, played back the corresponding audiovisual. The allocation of the real and simulated audio stimuli to "A" and "B" was randomised, with one false test included per participant. Participants were asked, "Which audio sample is the simulation?" and could select one of the following options "Audio A", "Audio B", or "They're the same". The third option was included to account for the possibility that participants could not distinguish any difference between the stimuli, and to test whether they could identify the false option. Participants were then asked to rate the level of difference, "How different are the two audio samples?", on a continuous scale ranging from 1 "They're the same" to 5 "Very different". Once both questions had been completed, participants had the option to answer an open-ended question written question, "Why do they sound different?". The samples had to be listened to in their entirety before the next one could be played. There were unlimited replays for all the samples in Section 2, but participants were advised to limit to the replays to three each. There were no time-based restrictions for answering the questions.

Of the pool of 64 audio stimuli, samples were selected randomly with 37 samples for Section 1 and 15 sample pairs for Section 2. The presentation order was randomized but avoided equivalent stimuli being played in succession. For Section 1 of the survey, the first four audio recordings played at the beginning of the survey were later repeated at the end of the survey to see if familiarity with the test environment altered their responses. The majority of participants had one false option per section, except for 15 participants who had 3 false options in Section 1 and 1 false option in Section 2. The mean time taken by participants to complete the full test was 45 minutes.

5 RESULTS

The data gathered from the surveys was analysed with the help of R Studio. The ANOVA statistical method was applied to Sections 1 and Sections 2 separately and further analysed.

5.1 Section 1 Results

The overall results gathered from all the participants for Section 1 were analysed to determine the differences between the means of unrelated groups and the variance within and between groups. The groups the results were divided into were Sample (Audio sample), Condition (Real or AI), Room Type (OGGB, Leech, 1202, Strata), Noise Type (Music or Speech), Movement (Stationary or Rotating). The ANOVA analysis evaluated the interaction of Room Type, Noise Type and Condition.

The most significant effect was observed for Room Type with a p-value of 2.56e-06. The change in room types had a significant statistical impact on the ratings given by the participants. The Noise Type (Music or Speech) did not have a significant effect on how participants rated the plausibility of the recordings. No significant difference in plausibility was observed for the Condition group, showing that Real recordings were rated similarly to AI recordings in terms of plausibility, as shown in Figure 6.

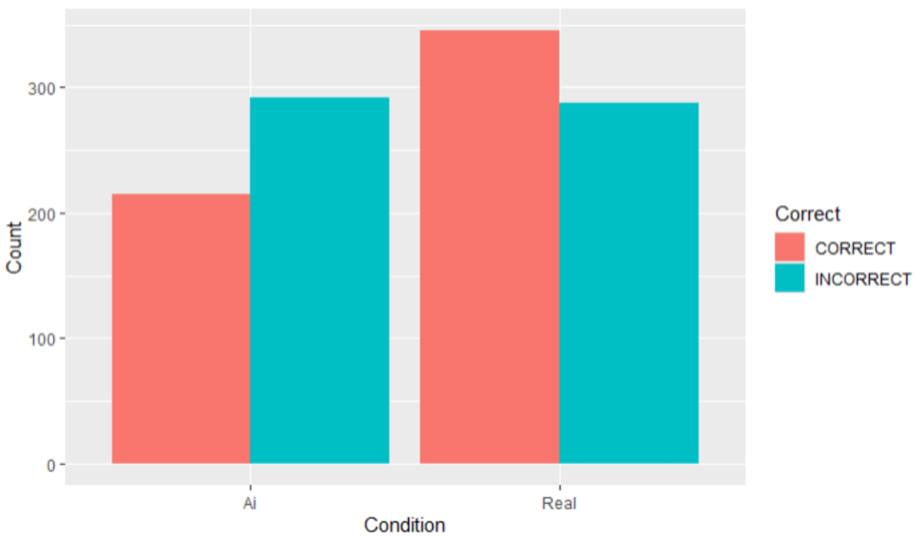


Figure 6: Frequency of correct vs incorrect responses by Condition (Real vs. AI)

The mean plausibility rating for stimuli recorded in Real Rooms was found to be MRe = 3.22, while the mean plausibility for AI simulated auralisations was found to be MAi = 3.26, as shown in Figure 7. The results suggest that the participants rated the real and auralised audio recordings to be similar in plausibility, with the auralisations being rated slightly more plausible by 0.04.

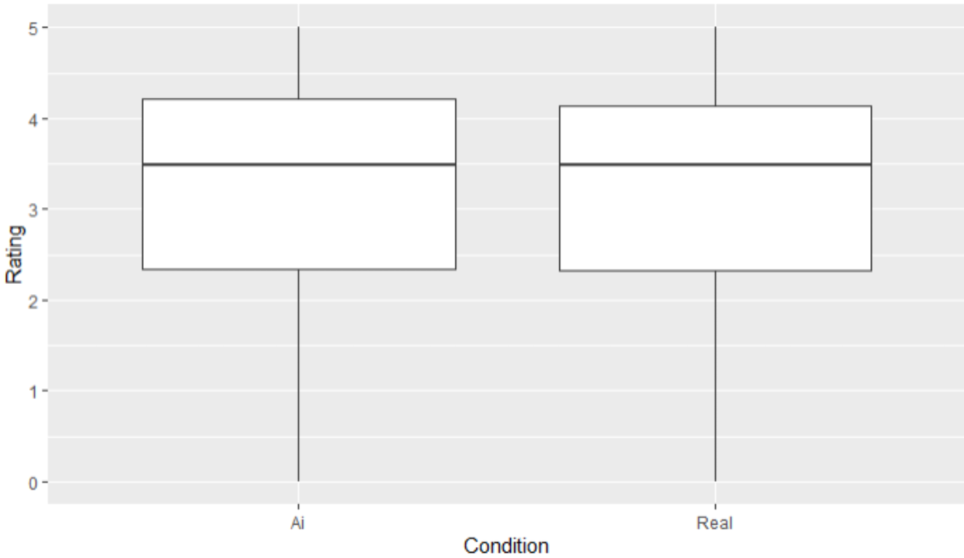


Figure 7: Rating of plausibility by Condition (Real vs. AI)

5.2 Section 2 Results

Section 2 consisted of comparing two audio recordings together and asking the participant to subjectively assess and decide which was simulated or if the two audio samples sounded the same. 62% of the total responses incorrectly identified the simulated audio (38% identified correctly). Of the incorrect responses, 15% were identified as being the same for cases where one audio sample was a real room and the other a simulation.

ANOVA analysis with the difference rating as the independent variable indicated the statistical significance of the room and movement variables. In this analysis, a higher difference rating meant that participants felt there was a greater difference between the real and simulated samples.

The mean difference rating for rotating stimuli was 2.56 compared to 2.03 for stationary stimuli, as indicated in Figure 8, meaning that participants felt there was a greater difference between the real and simulated samples when the head was rotating.

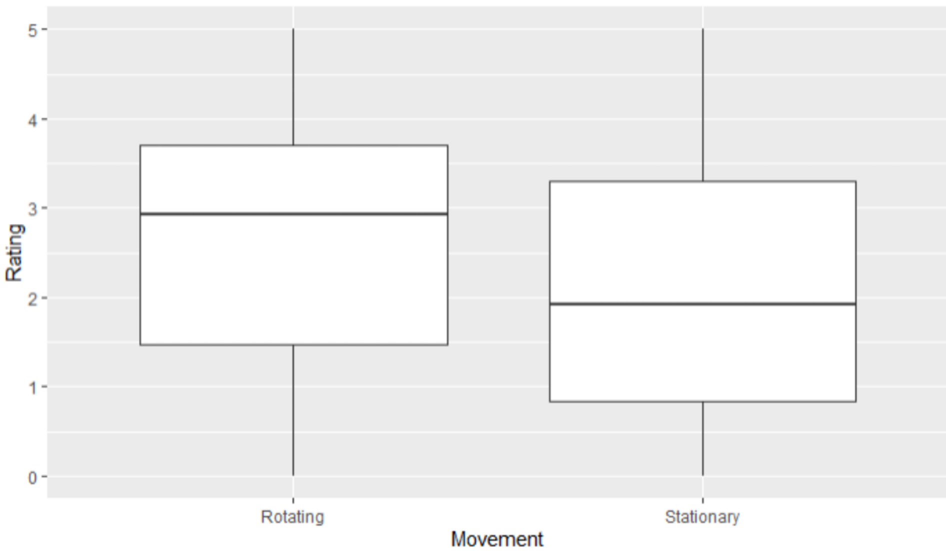


Figure 8: Box plot of difference ratings by Movement (Rotating vs. Stationary)

The mean difference rating for Meeting Room 401-1202 was 2.40, for Leech meeting Room 2.77, 2.34 for Strata Café and 1.66 for OGGB Meeting Room. As can be seen in the box plot of Figure 9, OGGB Meeting Room has a significantly lower difference rating and Leech had the highest difference rating.

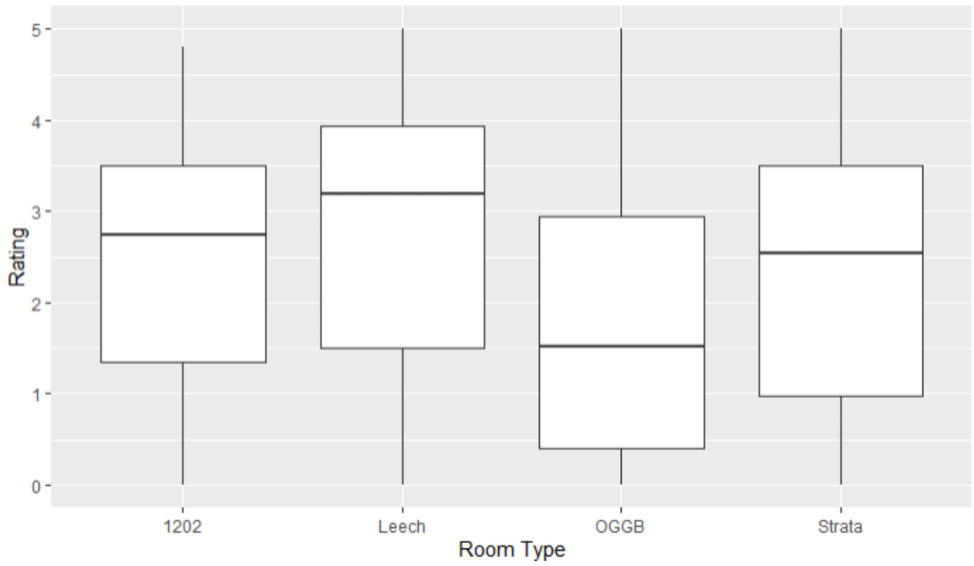


Figure 9: Box plot of difference ratings by Room Type

5.3 Written responses

During the tests, participants were asked to briefly explain their subjective impressions of why they may have rated the rooms differently. Some participants correctly identified the auralisation for rotating far speech in Meeting Room 1202 with their reasoning that the reverberance of the AiHear simulation was shorter than expected, as though they were closer to the speakers than shown in the video. Similar results can be seen in analysis of Stationary Far Speech of OGGB Meeting Room, with several participants commenting on how the sound feels too close in the auralisation. The auralisation of Far Rotating Speech in Strata Café sounded too reverberant to several participants, creating a feeling of different depths and a sense of space that did not match the video of the room.

6 DISCUSSION

The listening test results indicated that participants struggled to accurately identify the AiHear simulated audio, even when it was played alongside a real recording from the same room. This difficulty persisted even in cases where participants reported a high difference rating, suggesting that, although they perceived differences between the real and simulated audio, they were not able to consistently attribute these differences to inaccuracies in the simulation. This finding highlights the effectiveness of the AiHear audio engine at creating a sound experience that closely mirrors real-world recordings, as participants were often unable to distinguish between the real or simulated rooms.

The Leech meeting room, characterized by a much higher average reverberation time compared to the other rooms, received notably lower plausibility ratings. This outcome suggests that the high reverberation in this room influenced participants' perceptions, likely due to limitations in their internal reference for spaces with such high reverberance in a relatively small volume. As participants indicated in written feedback, the reverberance or "echo" in the Leech room did not match their expectations for a room of its size, leading to a sense of acoustic mismatch in both the real recordings and simulations.

For the remaining test conditions, there was no significant difference in plausibility ratings between moving and stationary sounds for both real recordings and simulations. The frequency with which participants correctly identified simulations was similarly unaffected by these movement conditions, indicating that the spatial characteristics of moving versus stationary stimuli did not meaningfully influence participants' abilities to discern real from simulated audio. Although the difference rating for rotating versus stationary stimuli was not statistically significant, there was a minor trend suggesting that rotating stimuli may be perceived as more distinct in the real rooms. This may imply that movement dynamics could affect perceived differences, although not to a statistically significant degree in this study.

The age and gender of participants did not play a significant role in the results. Whether participants had an acoustics background also had no significant influence on the results.

7 CONCLUSIONS

This study's findings consistently showed little difference in plausibility ratings between simulated and real recordings, challenging the implicit assumption that real recordings inherently represent a more "realistic" auditory experience. This lack of significant difference in ratings suggests that well-designed simulations can provide a perceptually plausible experience comparable to real rooms, supporting the use of AiHear simulations for realistic, immersive audio applications where exact replication may be unnecessary.

8 FURTHER WORK

Development of the AiHear software system is a continuing work in progress. Refinement of the auralisation algorithms is ongoing, including work on increasing the number of early reflections. It is theorised that this will improve the spatial localisation of sources and overall realism of the reverberated sound within the auralisations, helping to reduce the perceivable differences between real rooms vs. simulations. The binaural recordings of the four real rooms from this study provide a good benchmark of how rooms should sound for comparison purposes.

9 ACKNOWLEDGEMENTS

The author would like to acknowledge the outstanding effort put in by the students, Hannah and Sophia, to get this project completed on-time and to such a high standard. They dedicated literally hundreds of hours recording the real rooms, designing the subjective survey and then conducting the survey on an impressive 30 participants. Acknowledgement and thanks also go to Dr Andrew Hall, Dr George Dodd and Gian Schmidt of the University of Auckland for their expert knowledge, technical input and supervision of this project. Special thanks go to Jack Wong of NDY for his part in creating AiHear. Without his coding skills, none of this would be possible.

REFERENCES

Axenova, Sophia. 2024. *Auralisation vs Reality: How Close Can We Get to the Real Room?* Part IV Project Research Report ME114-2024. Department of Mechanical and Mechatronics Engineering, University of Auckland.

Beresford, Tim, and Jack Wong. 2023. "A Portable Augmented/Virtual Reality Auralisation Tool for Consumer-Grade Devices with Companion Desktop Application." In *Proceedings of Inter-Noise 2023*, Chiba, Tokyo, Japan. Institute of Noise Control Engineering.

Bresciani, A. P. 2024. *Physical and Perceptual Prediction of Wind Turbine Noise*. PhD diss., University of Twente, Netherlands.

Busselle, R. W., and B. S. Greenberg. 2000. "The Nature of Television Realism Judgments: A Reevaluation of Their Conceptualization and Measurement." *Mass Communication & Society 3* (2–3): 249–268.

Diemer, J., and P. Zwanzger. 2019. "Development of Virtual Reality as an Exposure Technique." *Der Nervenarzt.* 2019 July: 90(7):715-723.

GRAS Sound & Vibration. 2020. *Instruction Manual – GRAS 45BB KEMAR Head and Torso, GRAS 45BC KEMAR Head and Torso with Mouth Simulator.* LI0085, rev. 2.

Grice, M., and V. Hazan. 1996. "The SUS Test: A Method for the Assessment of Text-to-Speech Synthesis Intelligibility Using Semantically Unpredictable Sentences." *Proceedings of the Institute of Acoustics* 18 (9).

Hill-Marks, Hannah. 2024. *Auralisation vs Reality: How Close Can We Get to the Real Room?* Part IV Project Research Report ME000-2025. Department of Mechanical and Mechatronics Engineering, University of Auckland.

Hofer, Matthias, Tilo Hartmann, Allison Eden, Rabindra Ratan, and Lindsay Hahn. 2022. "The Role of Plausibility in the Experience of Spatial Presence in Virtual Environments." *Frontiers in Virtual Reality* 1.

ISO (International Organization for Standardization). 2008. *ISO 3382-2: Acoustics – Measurement of Room Acoustic Parameters – Part 2: Reverberation Time in Ordinary Rooms.* Geneva: ISO.

Lindau, A., and S. Weinzierl. 2011. "Assessing the Plausibility of Virtual Acoustic Environments." In *Proceedings of Forum Acusticum*, 1187–1192.

Slater, Mel. 2009. "Place Illusion and Plausibility Can Lead to Realistic Behaviour in Immersive Virtual Environments." *Philosophical Transactions of the Royal Society B: Biological Sciences* 364 (1535): 3549–57.

Health 8 (6): 1847–64. doi:10.3390/ijerph8061847.