SALFORD ACOUSTICS RESEARCH CENTRE

University of Salford MANCHESTER

Annex 63: Psychoacoustics of Air Source Heat Pump Noise

Prof. Antonio J Torija Martinez

Psychoacoustics: Why is it important?

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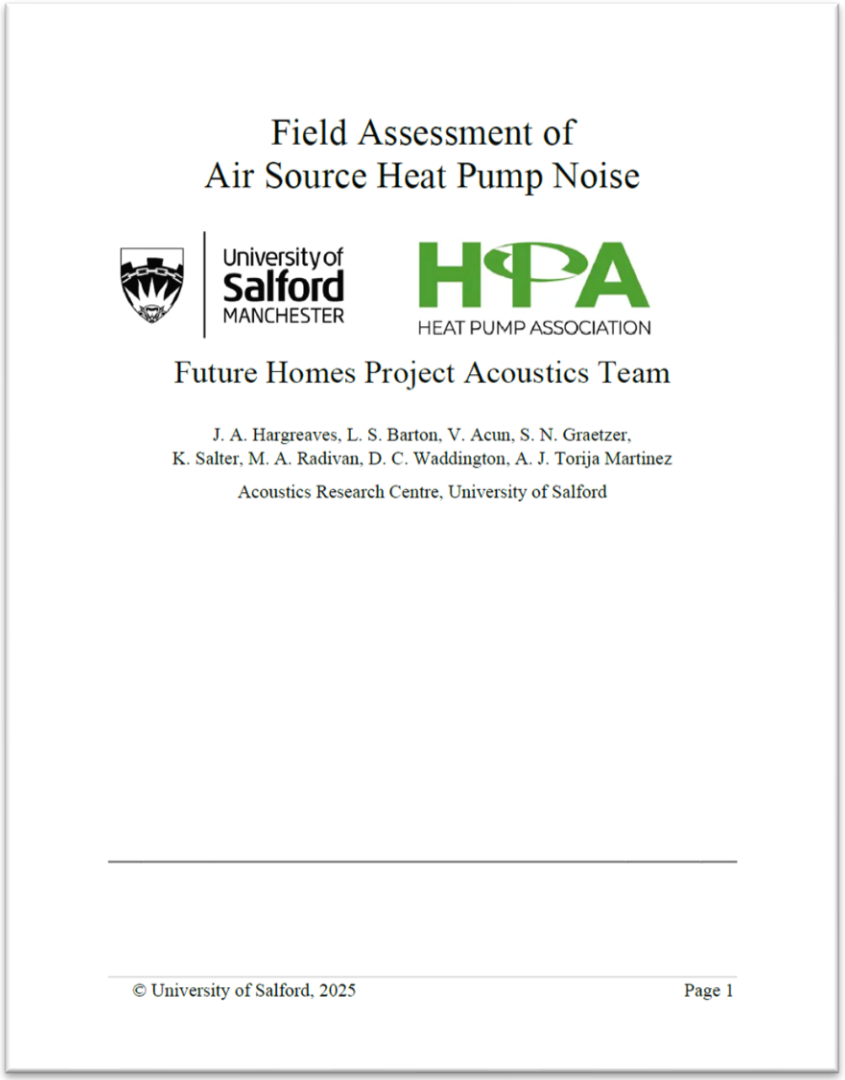
Nottingham Dec 2024 / Jan 2025

- 4 properties with adjoining gardens
- Nearby ‘A’ road
- Results published in technical report



Field Assessment of
Air Source Heat Pump Noise

University of Salford MANCHESTER

HPA HEAT PUMP ASSOCIATION

Future Homes Project Acoustics Team

J. A. Hargreaves, L. S. Barton, V. Acun, S. N. Graetzer,
K. Salter, M. A. Radivan, D. C. Waddington, A. J. Torija Martinez

Acoustics Research Centre, University of Salford

Nottingham Field Assessment

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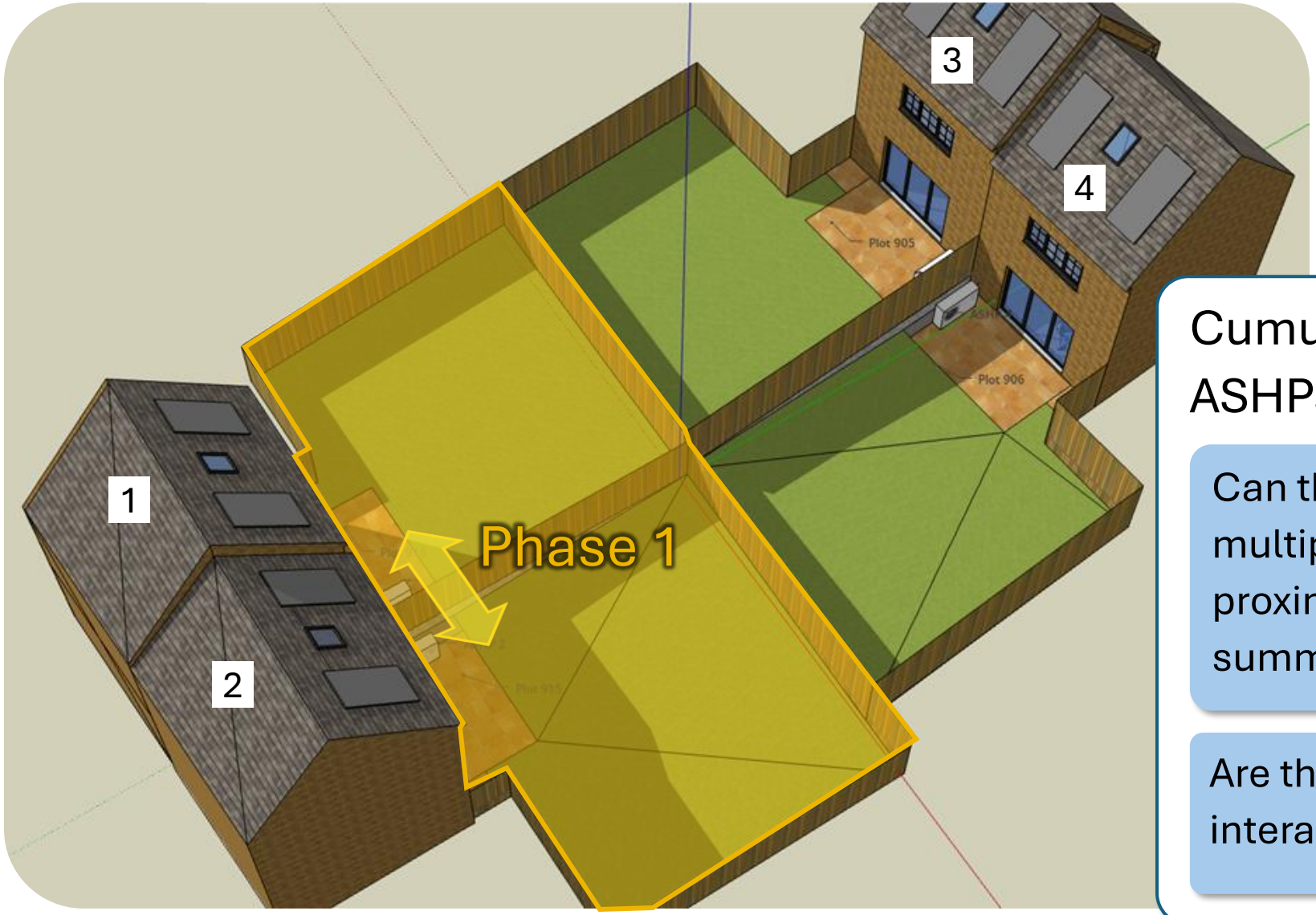


Cumulative effects of multiple ASHPs in close proximity:

Can the combined level of multiple ASHPs operating in close proximity be estimated by simply summing the power?

Are there low frequency sound interaction effects?

Phase 1: Methodology

Microphone Arc

- 2.5m radius
- 9 microphones at 20° spacing

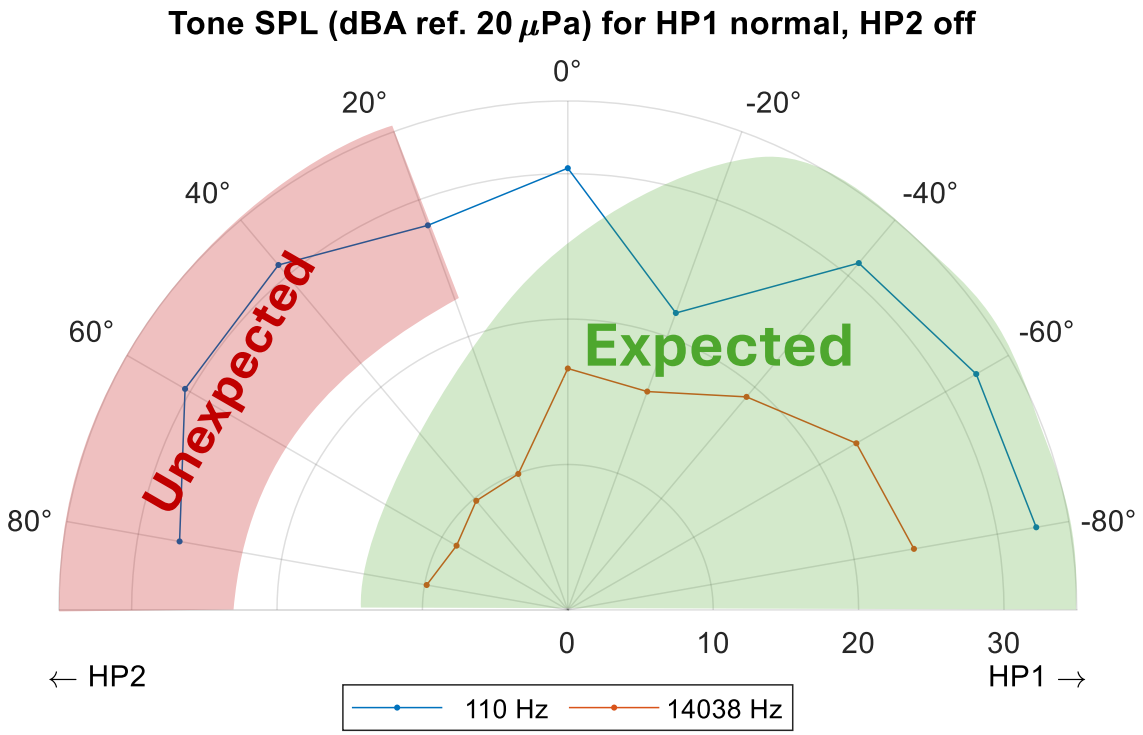
Aim to capture directivity

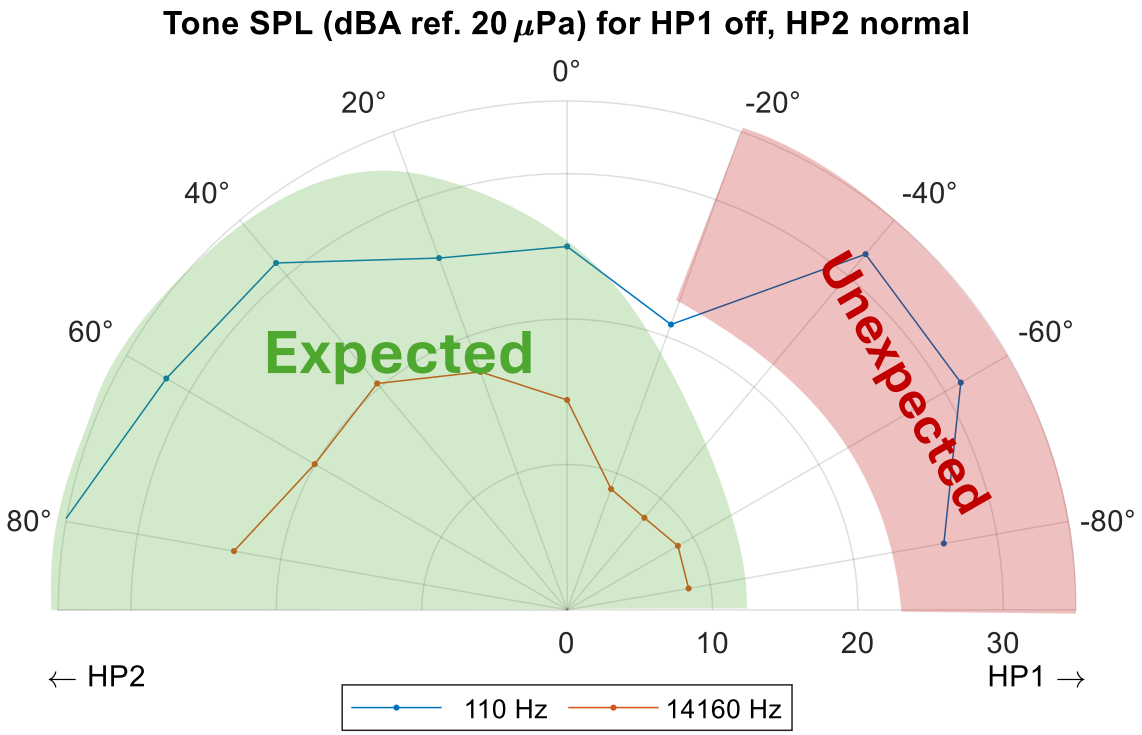
- Effect of ASHP orientation
- Effect of fence

Additionally…

- Tonality Assessment
- Fluctuation Strength Analysis (beating)

Tonality Assessment - Directivity





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Findings

- Perceptible tones were detected, both at low and high frequencies
- Some low-frequency tones showed minimal attenuation by the wooden fence, so were present at the neighbouring property
- Beating thought to possibly be heard by investigators* but analysis of measured data shows nothing above perceptible thresholds

Further Work

- Further experimental analysis of fences is required, to better understand their attenuation and to propose higher-performance designs
- Further work is required to understand the cumulative effect towards human response

* This was only heard behind the ASHP, an unrealistic listening position

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Placement Impact on Heat Pump Acoustics

IEA HPT Annex 63

IEA HPT ANNEX 63

TASK 3: Psychoacoustics of Heat Pumps

Joint Experiment on the Cumulative Effect of ASHP Noise

10 Institutions from 6 Countries:

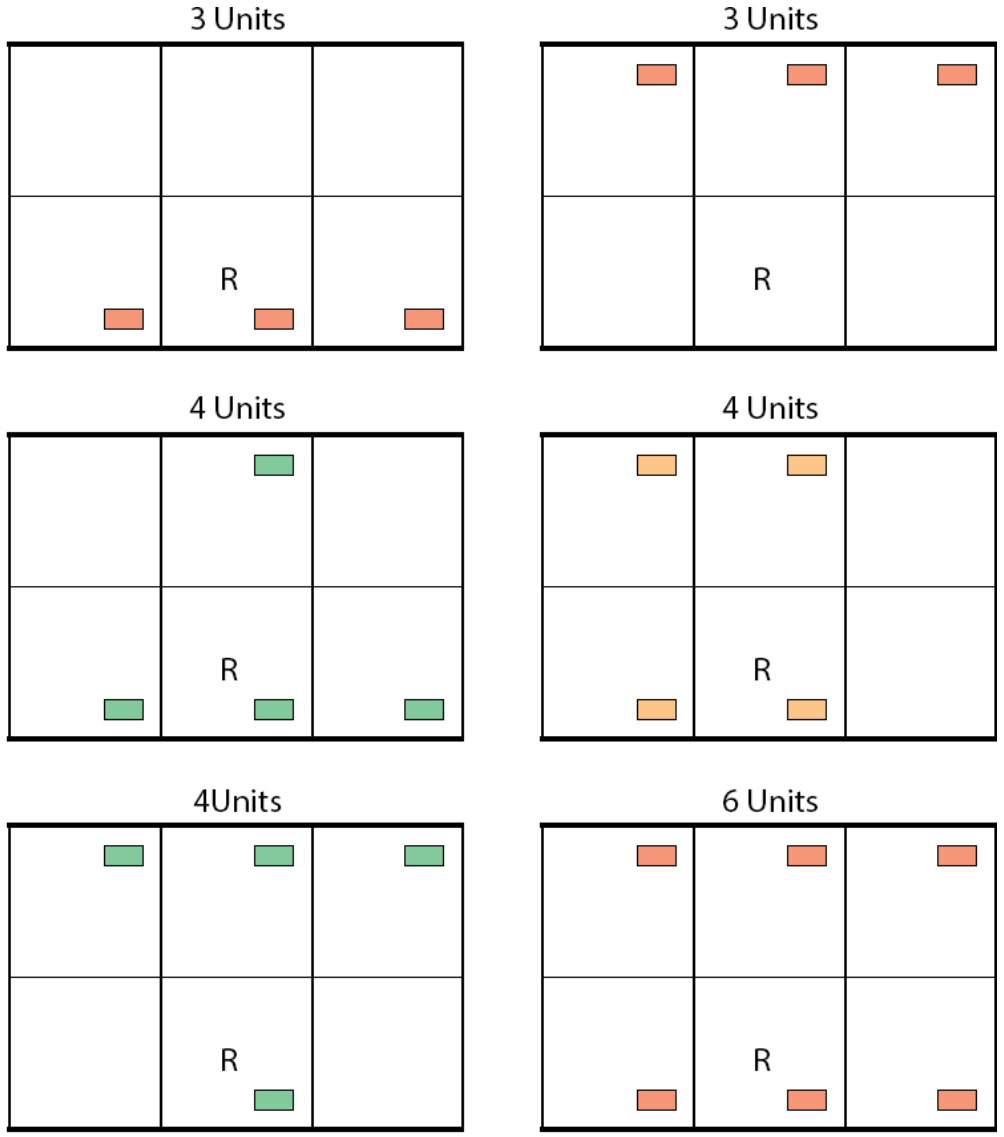
- University of Salford (UK)
- HEAD Acoustics (Germany)
- RWTH Aachen University (Germany)
- IBP Fraunhofer (Germany)
- Peutz (Netherlands)
- CETIM (France)
- Austrian Academy of Sciences (Austria)
- Politecnico di Milano (Italy)
- Universita degli Studi della Campania Luigi Vanvitelli (Italy)
- RISE (Sweeden)

Experimental Design

The experiment consists of three parts:

- Part 1: single ASHP (focus on tonality, also ambient background).
- Part 2: two ASHPs (focus on interaction effects and distance).
- Part 3: three to six ASHPs (focus on interaction and cumulative effects).
- Data collection across 10 sites.158 males (58.3%) and 113 females (41.7%), with a total of 271 participants.

Scenario Examples



Preliminary Findings

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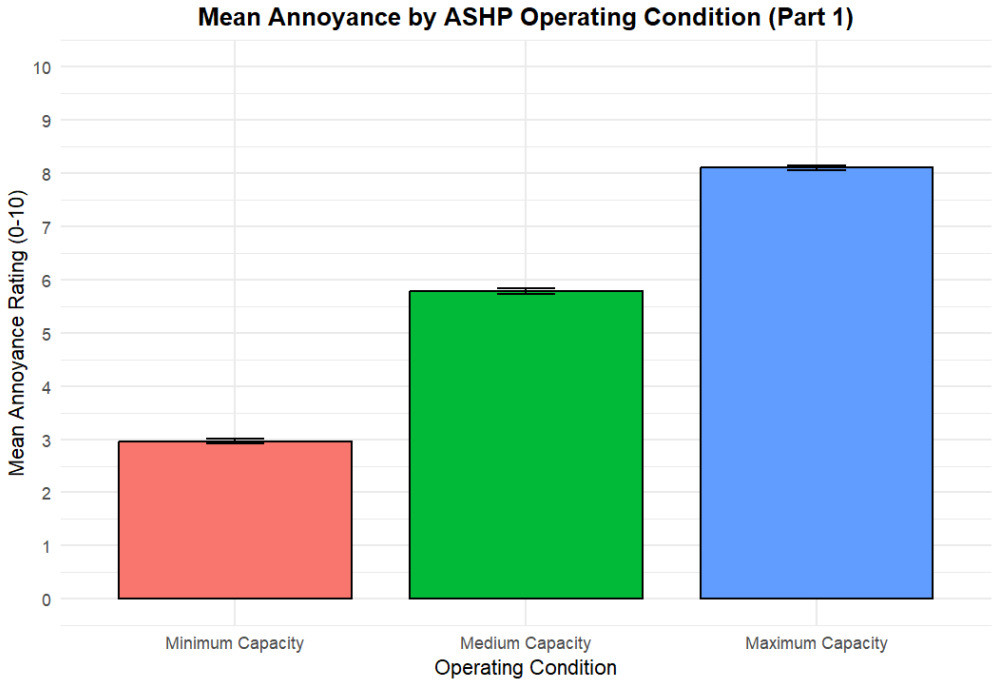
RQ: How do different operating conditions affect the annoyance caused by ASHP noise emissions?



Part 1 Operating Conditions:

- There is a clear and statistically significant difference between annoyance responses given to different operating conditions
- Noise emissions from the nearest ASHP are the main contributor to annoyance

Preliminary Findings

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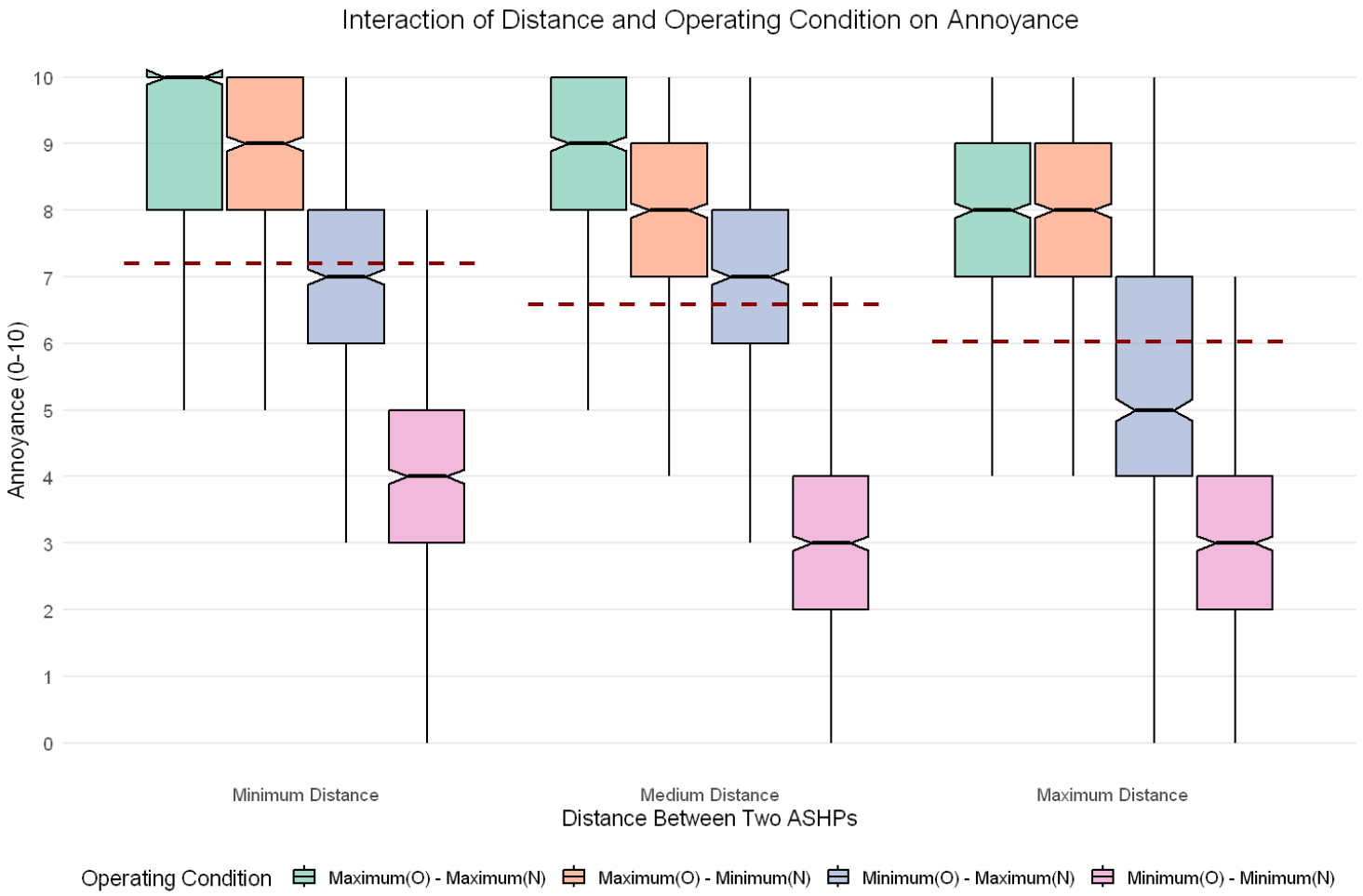
RQ: How do different operating conditions, and distance affect the annoyance caused by ASHP noise emissions?



Part 2 Interaction Effects:

- Strong influence of operating condition
- Closest ASHP driving annoyance
- Annoyance reducing with increase in ASHP distance

Preliminary Findings

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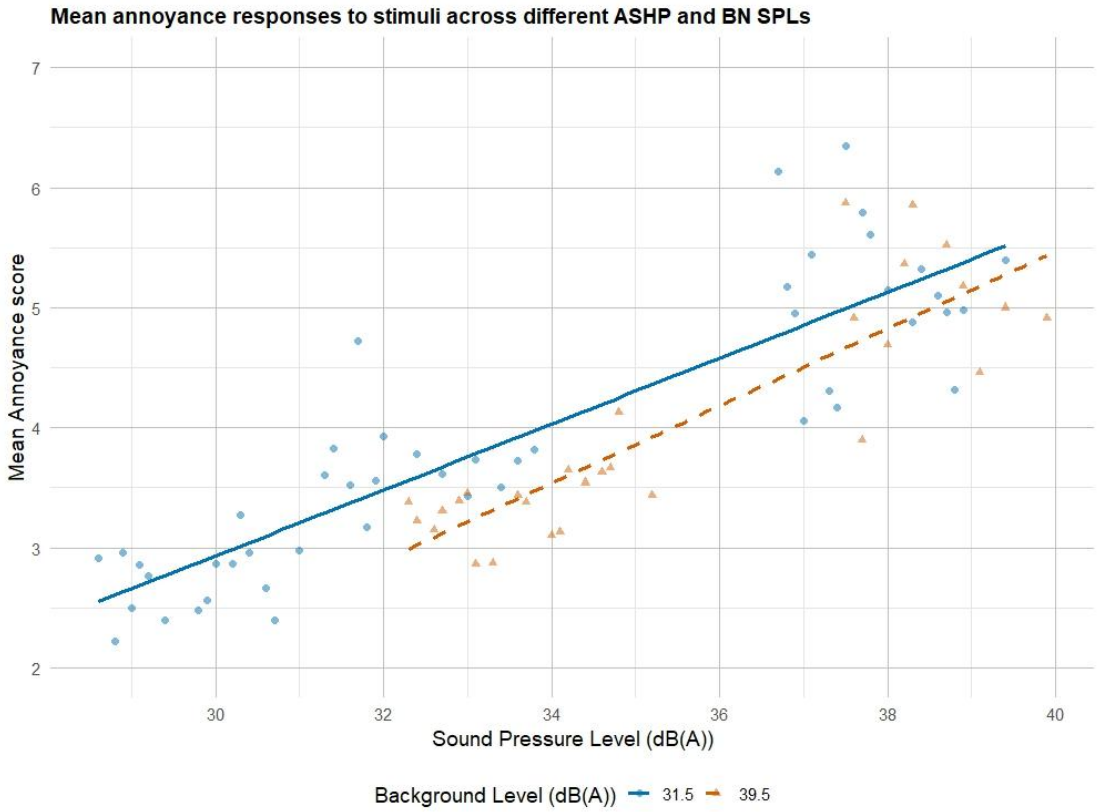
RQ: How do Ambient Background Noise levels affect annoyance caused by ASHP noise?

Future Homes Project Listening Test:



Higher background noise levels help mask heat pump emissions and reduce annoyance at lower combined sound levels.

- Masking is effective at low-to-moderate levels

Locally-led Innovation Accelerators delivered in partnership with DSIT, Innovate UK and City Regions

Department for Science, Innovation & Technology

UKRI Innovate UK

GMCA GREATER MANCHESTER COMBINED AUTHORITY

Preliminary Findings

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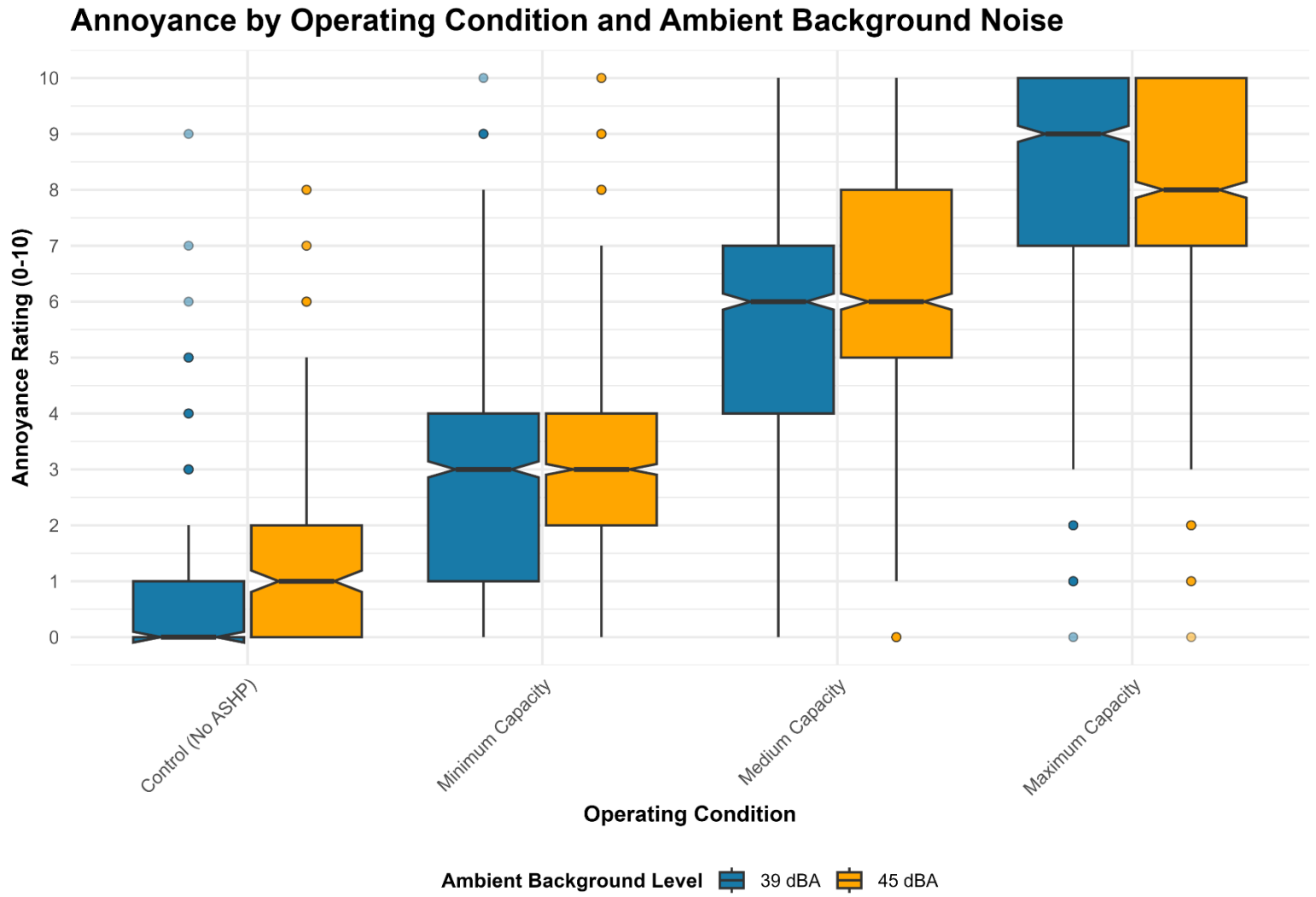
Annex 63 Listening Test:



Preliminary Findings

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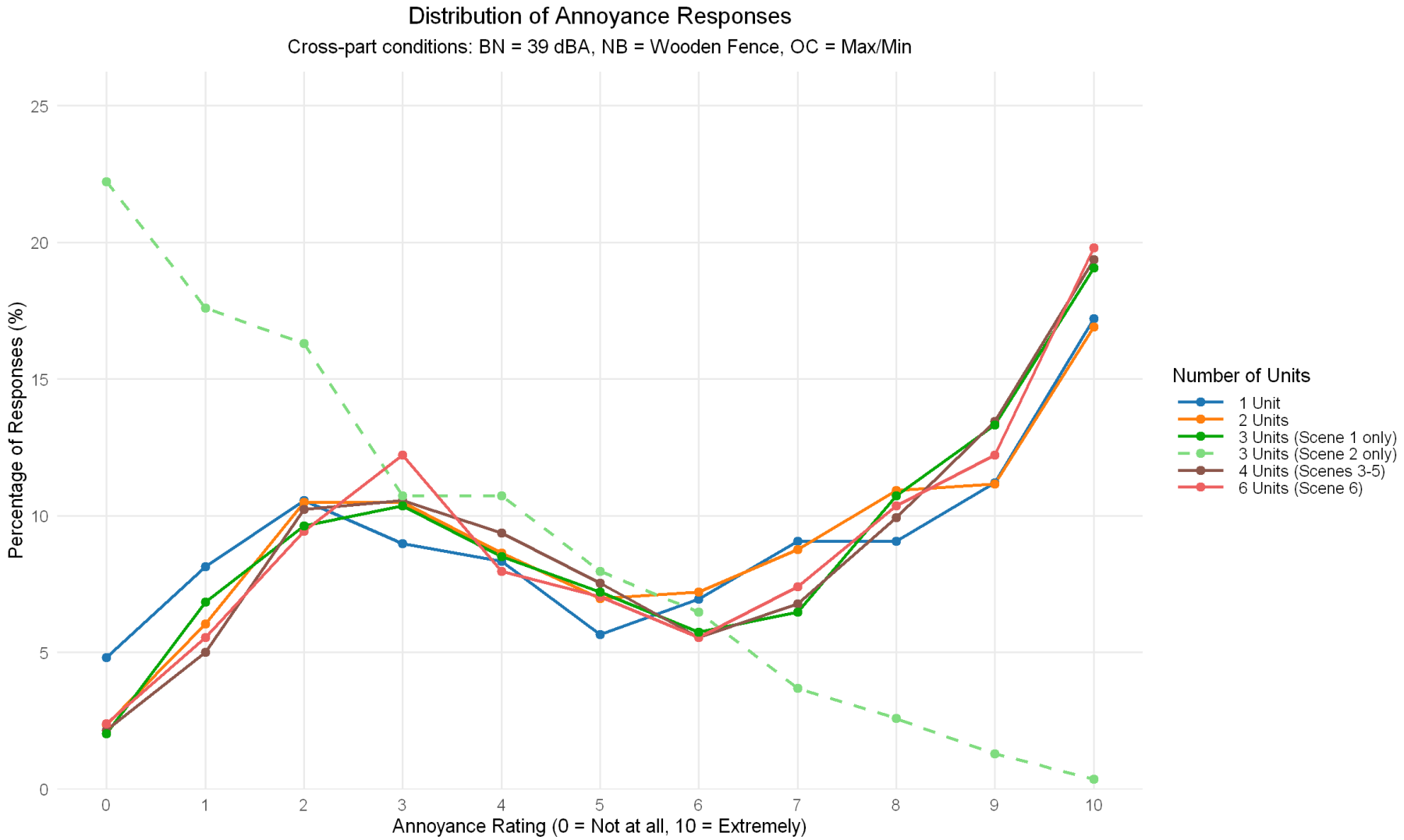
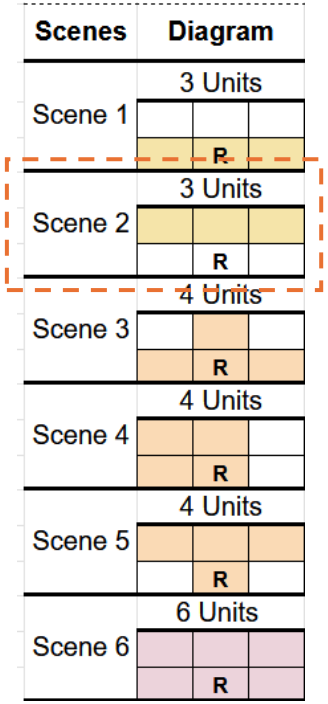
RQ: How does the Number of ASHP Units operating in a given area affect annoyance response?





Preliminary Findings

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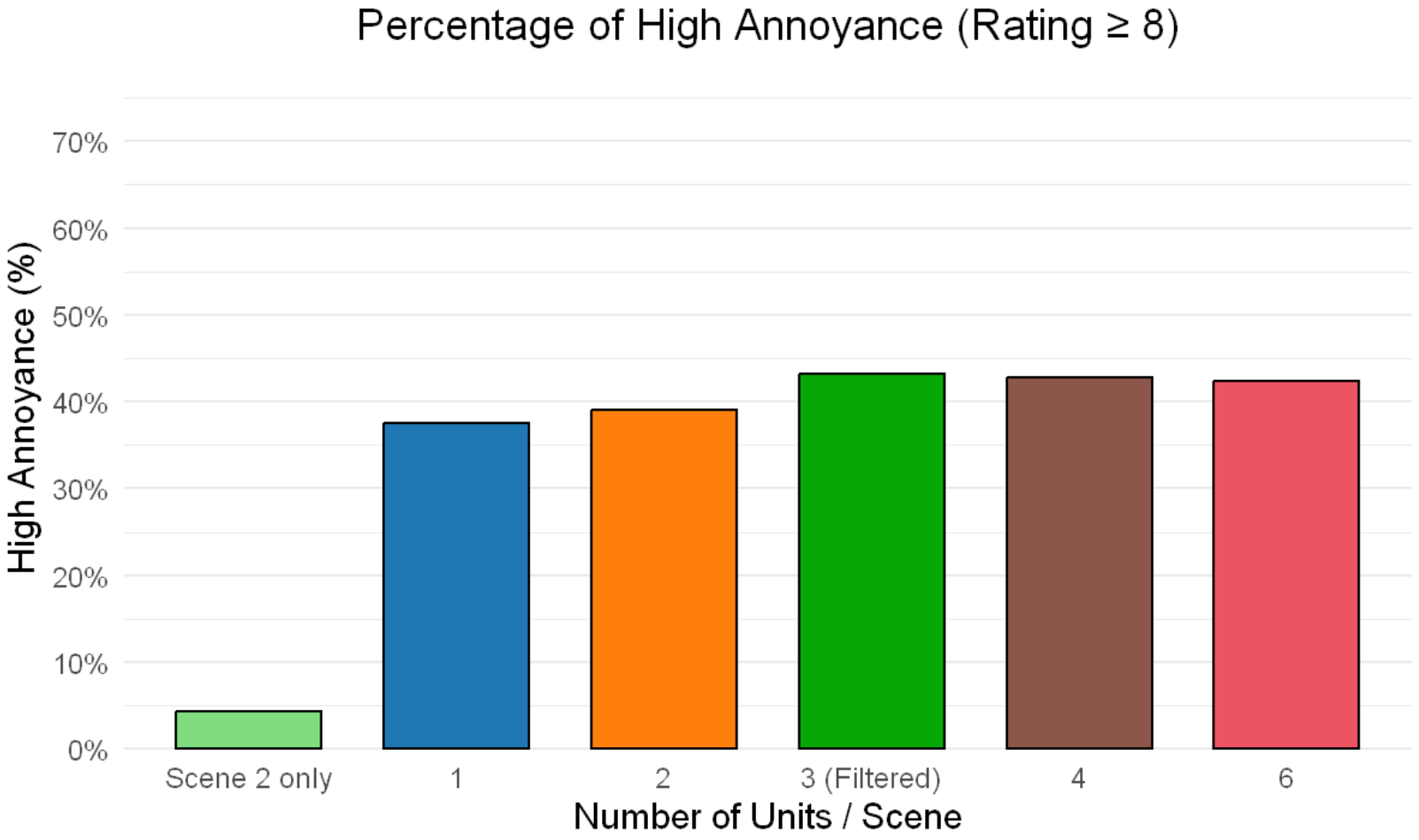

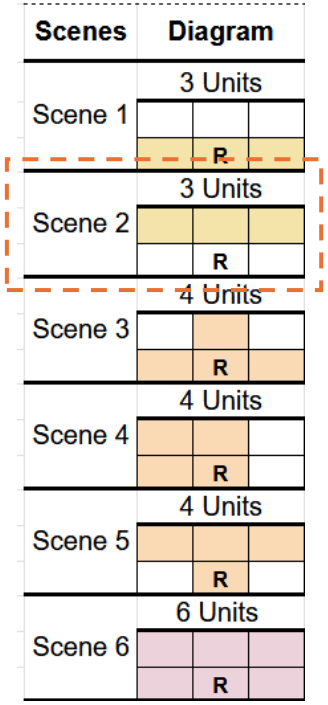

Preliminary Findings

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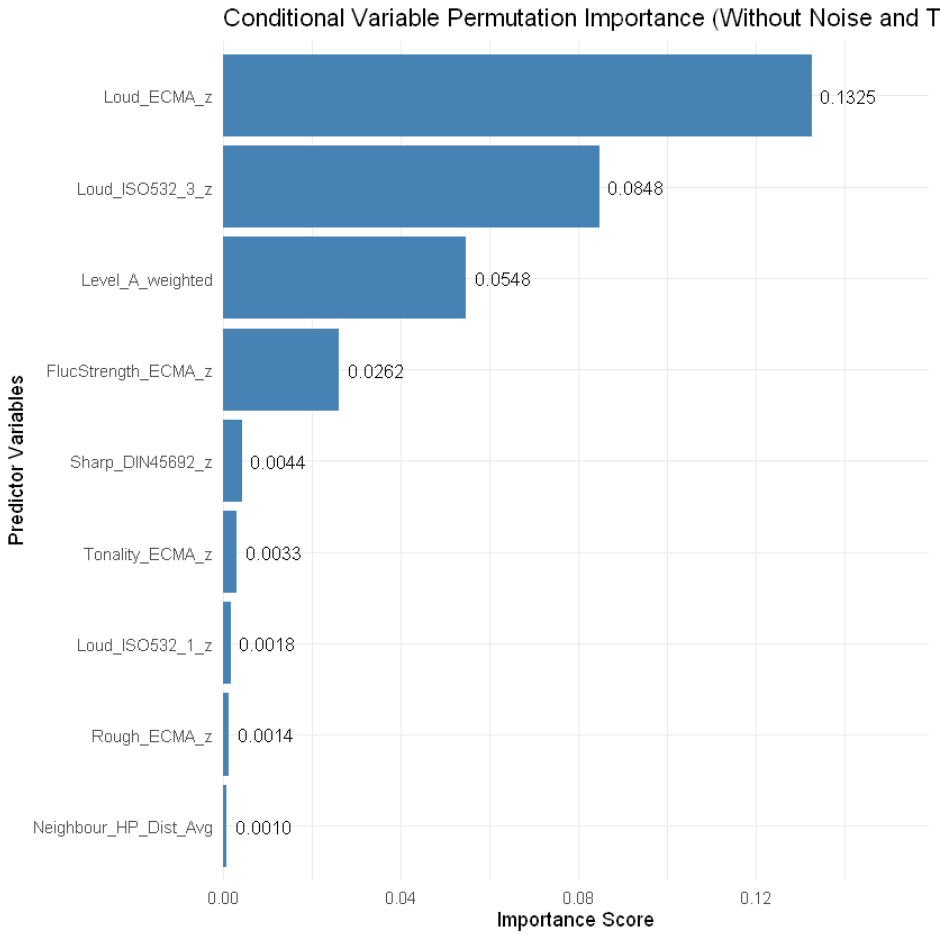

Conditional Random Forest

Used for evaluating the importance of different variables in predicting annoyance and deciding on which parameters to include in the GLMM analysis

Key Finding: Loudness-based metrics consistently emerged as the most important predictors.

Preliminary Findings

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Generalised Linear Mixed Models

Formula:

Annoyance ~ Loud_ECMA_z + Number_of_Neighbours + (1 | Participant_ID) + (1 | Site)

Loudness (ECMA)	Strong positive effect — every 1 SD increase in loudness significantly increases annoyance ($z = 85.81$, $p < .001$)
Number of Neighbours	Small but significant positive effect — more ASHP units nearby increases annoyance ($z = 6.00$, $p < .001$)

Loudness is by far the dominant driver of annoyance, but the number of units has a minimal contribution and requires further experimentation.

The model explains **97.7% of total variance** (conditional R^2), with loudness and number of neighbours alone accounting for **74.6%** (marginal R^2)
The gap between marginal and conditional R^2 shows that individual differences is a huge factor.

FHP – Acoustics: Team

Leading Team

Advisor

Acoustics Labs

Research Fellows

Research Assistant

PhD student

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University of Salford MANCHESTER

Thank you for your attention!

Prof. Antonio J Torija Martinez

A.J.TorijaMartinez@salford.ac.uk