



Measuring and Reproducing Urban Soundscapes

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The
Alan Turing
Institute



European Research Council
Established by the European Commission

About me!

- Acoustics Consultant at Newson Brown Acoustics in LA
- Soundscape and Acoustics Consultant at Hoare Lea in London
- PhD Student and PGTA at UCL

*Machine Learning and Regression
Modelling of Dynamic Urban
Soundscapes*





Why Soundscape?

Noise Pollution and the dB

- The decibel (dB) is the most commonly used index
- Not well correlated with human perception
- Efforts to improve this include things like adjusted level requirements for different kinds of noise sources and contexts
- Still concentrating on noise control rather than on designing overall environments
- Smart city design should focus on improving quality of life, which is heavily driven by perception, as opposed to strictly noise levels

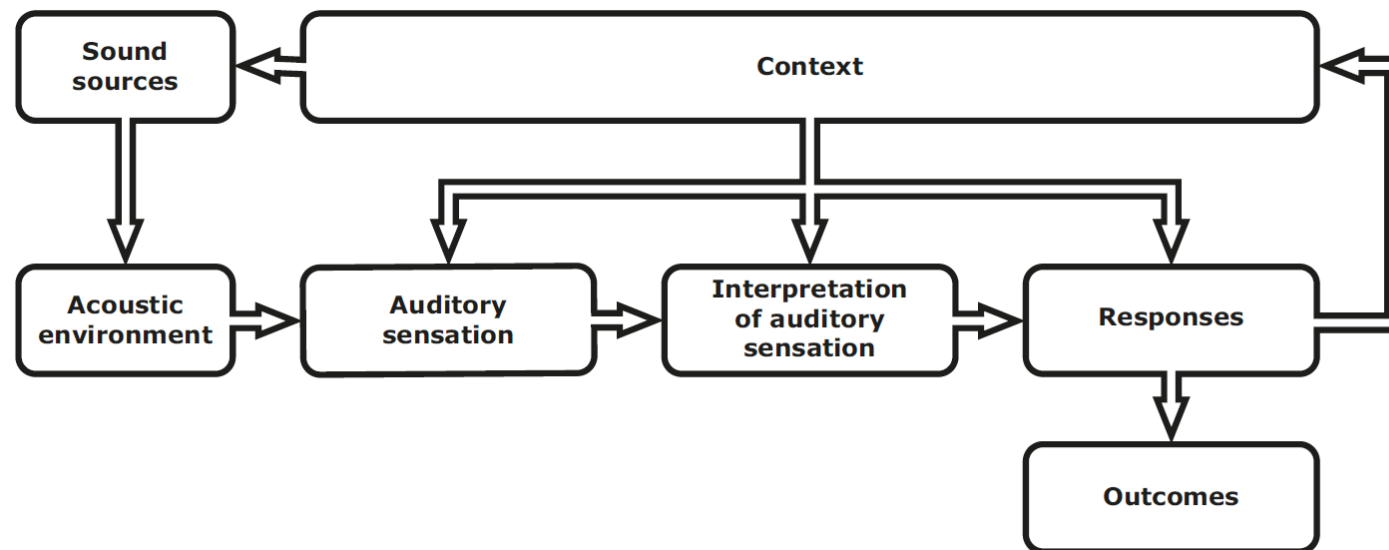
Soundscape in Legislation and Policy

- European Environmental Noise Directive 2002/49/EC
 - 5 year noise maps
 - “establish common assessment methods for ‘environmental noise’ [...] to **preserve quiet areas**”
- Welsh Government *Noise and soundscape action plan (2018-2023)*
 - “Air quality and **soundscape are addressed as a key component** of the natural and built environment, placing the issues on an equal footing with other objectives such as housing, transport and economic development.”
- ISO 12913 Acoustics – Soundscape - Parts 1, 2, & 3

Soundscape for Characterisation of Spaces

ISO 12913 Part 1:

The acoustic environment as perceived or experienced and/or understood by a person or people, in context



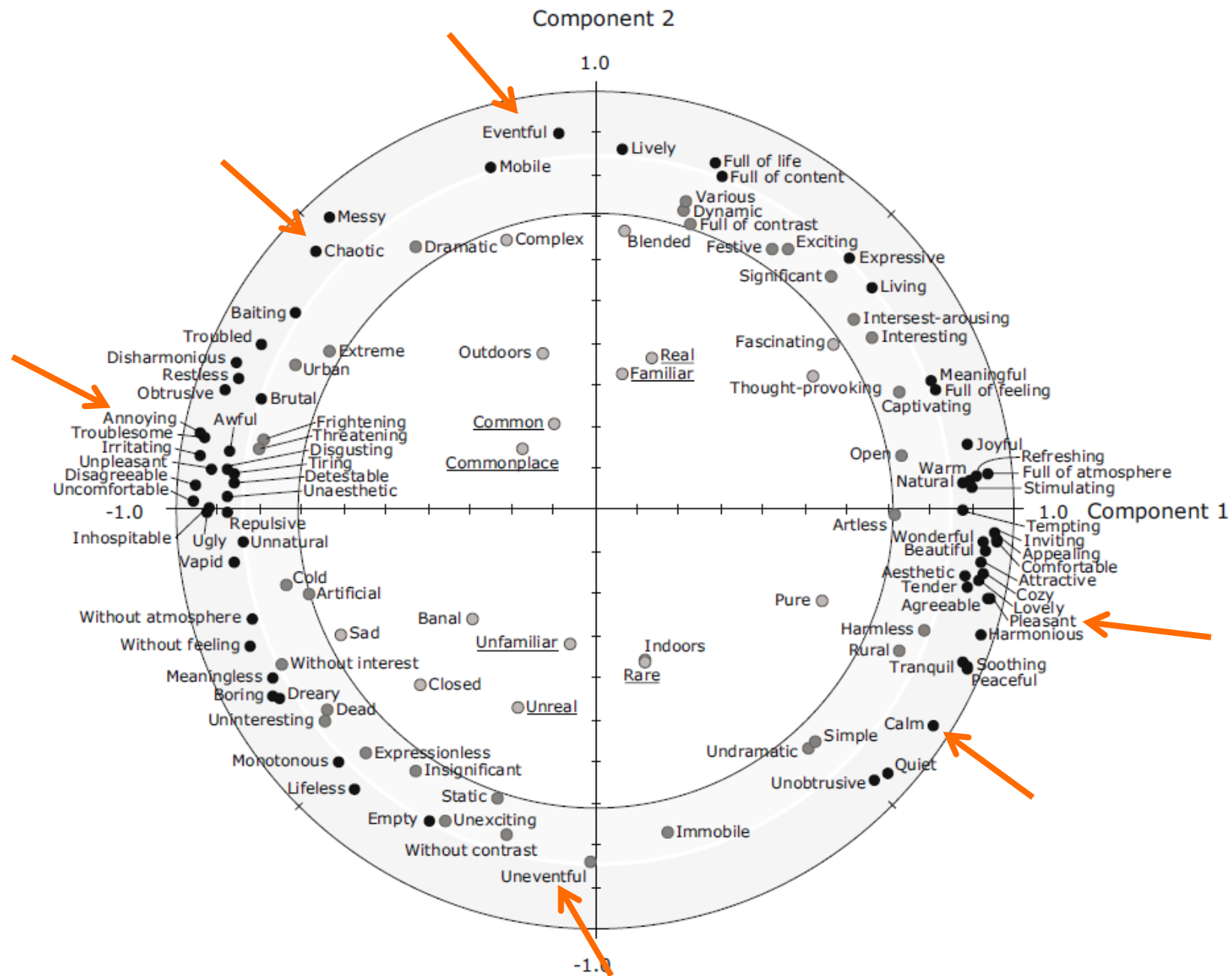
Soundscape for Characterisation of Spaces

ISO 12913 Part 1:

The acoustic environment as perceived or experienced and/or understood by a person or people, in context

But how do we measure perception?

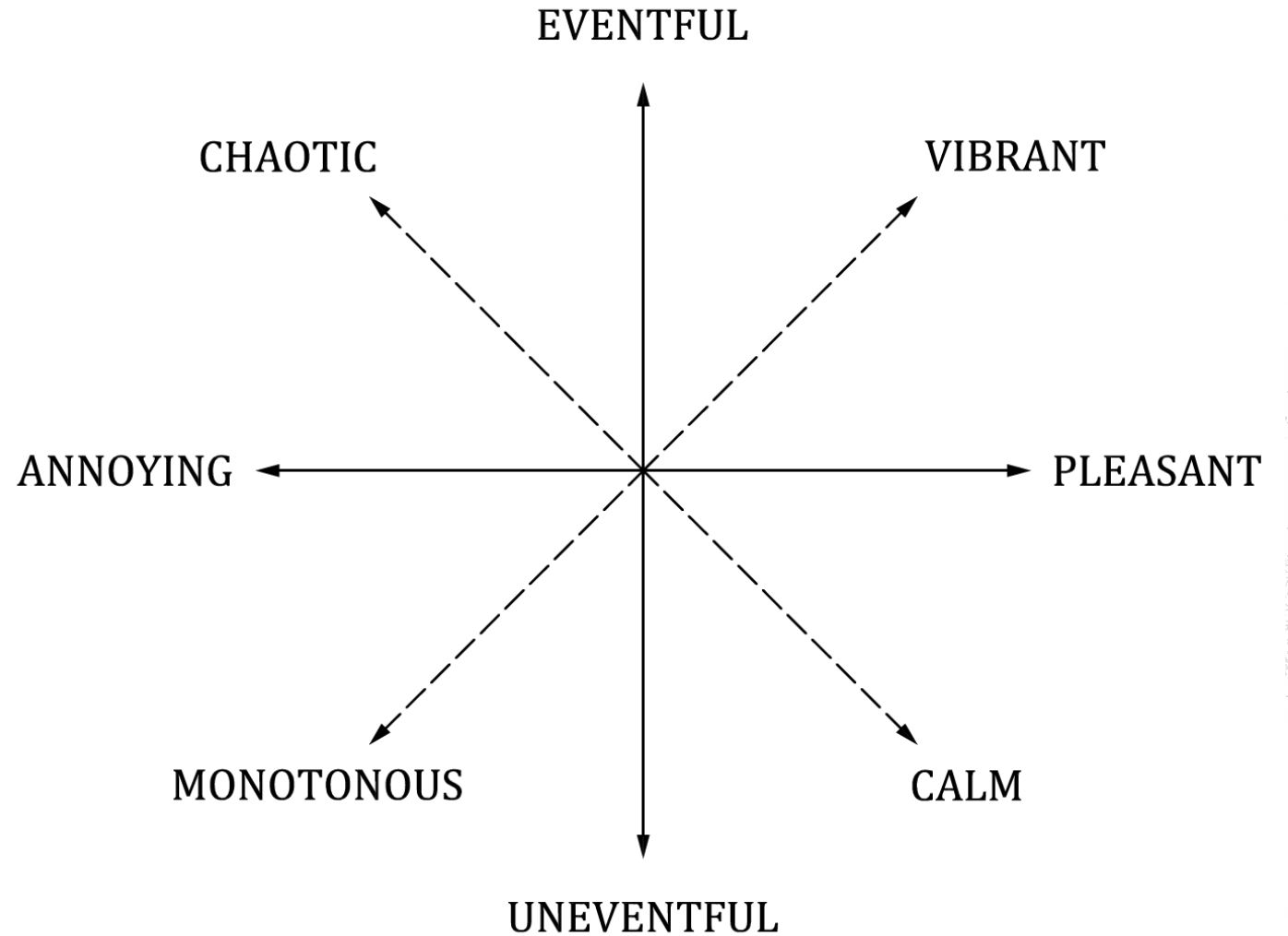
The Circumplex Model of Soundscape Perception



Axelsson, O., Nilsson, M.E., & Berglund, B. (2010). A principal components model of soundscape perception. *The Journal of the Acoustical Society of America*, 128(5), 2836-2846. doi.org/10.1121/1.3493436

The Circumplex Model of Soundscape Perception

ISO/TS 12913-3:2019 Acoustics - Soundscape - Part 3: Data analysis



Putting it into Engineering Practice

But how do we make use of this in engineering and design?

The SSID Project

- **Soundscape for Characterisation of Spaces**
- **Soundscape for Design of Spaces**

Requirements of the SSID

- Should be based on objective / measurable factors
- Should be generalisable to many different types of spaces
- Should be practical to implement without an excessive time or labour cost

Soundscape Database and Protocol

For more detailed information, see:

Mitchell, A.; Oberman, T.; et al.. **The Soundscape Indices (SSID) Protocol: A Method for Urban Soundscape Surveys—Questionnaires with Acoustical and Contextual Information.** Appl. Sci. 2020, 10, 2397.

The SSID Protocol

Design Goals

- Gather in situ soundscape assessments from the public, which can be further analyzed and utilized in designing a soundscape index
- Conduct recordings needed to reproduce the audio-visual environment of a location in a laboratory setting for conducting controlled experiments on soundscape.

Stages of the protocol

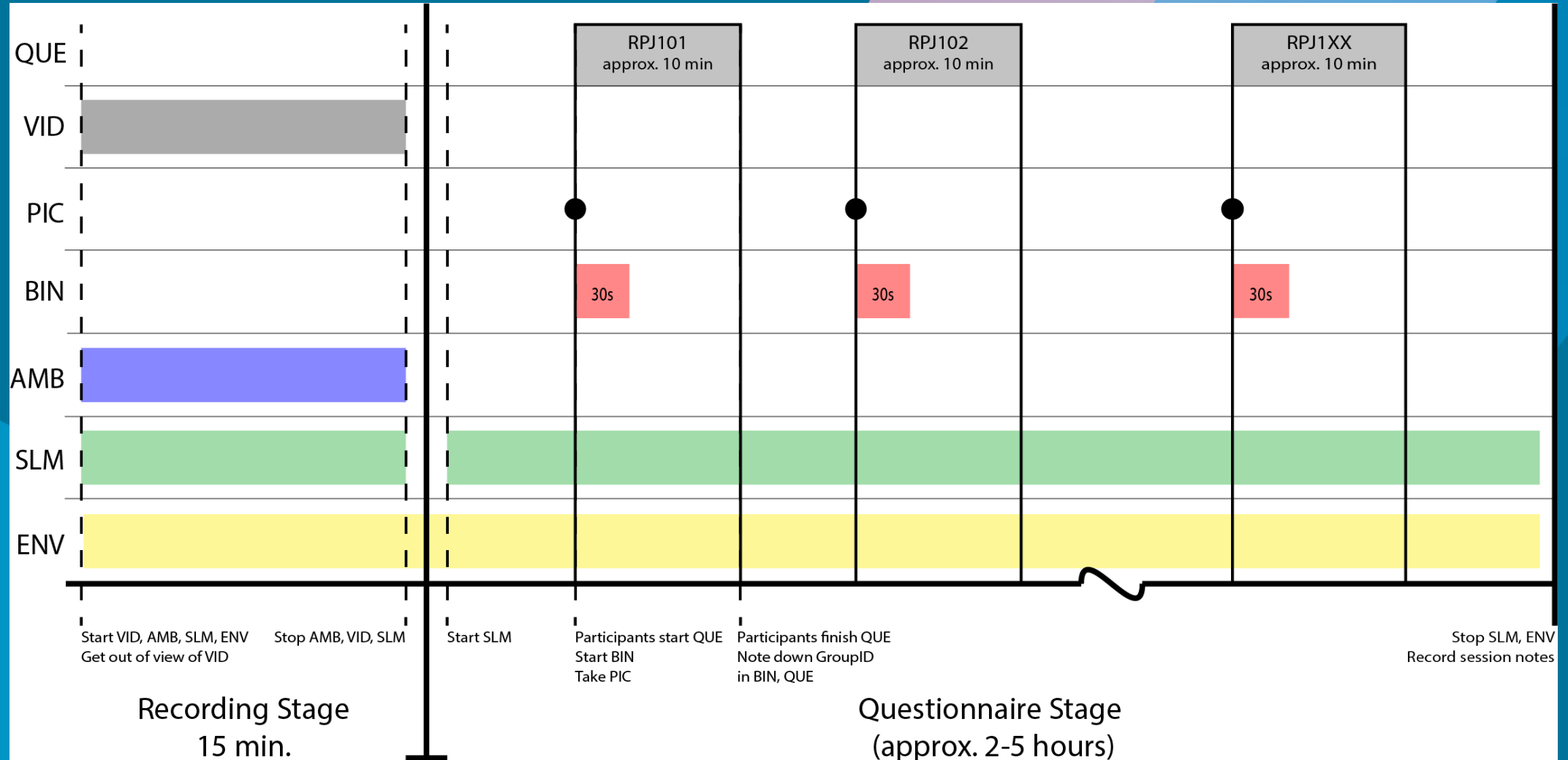
1. Recording Stage

Audio-visual recordings with 360 video, spatial audio, and calibrated SLM measurements

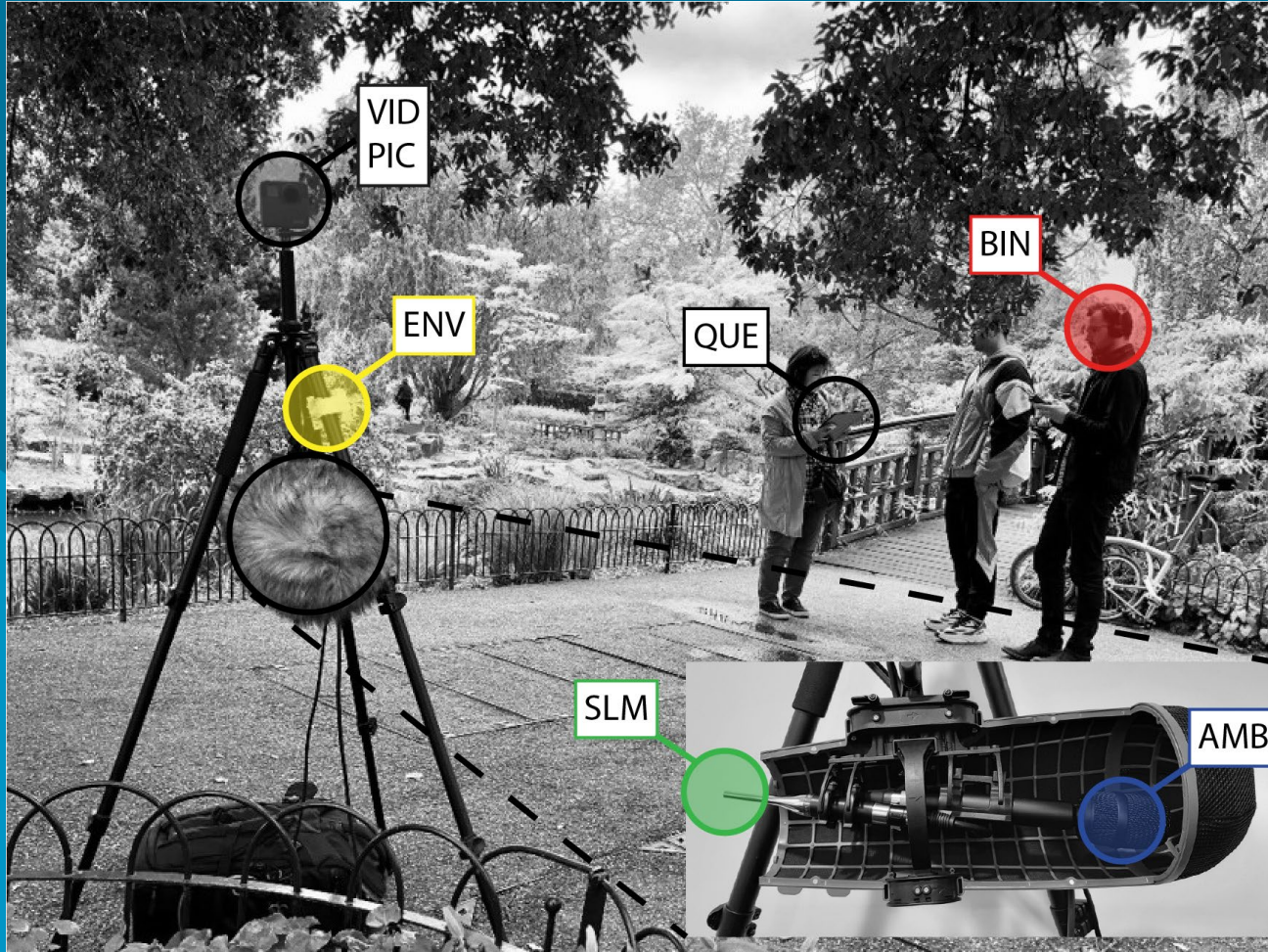
2. Questionnaire Stage

Repeated questionnaires with environmental data, continuous SLM, and individual binaural recordings and 360 photos for each group of respondents

Stages of the protocol

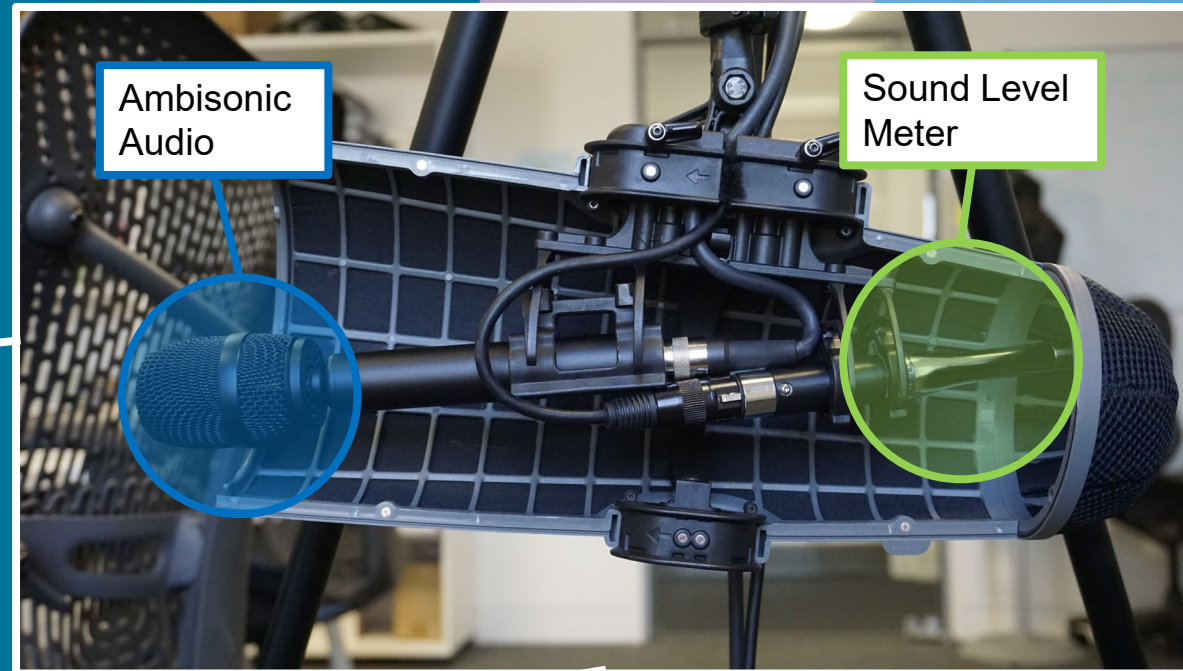
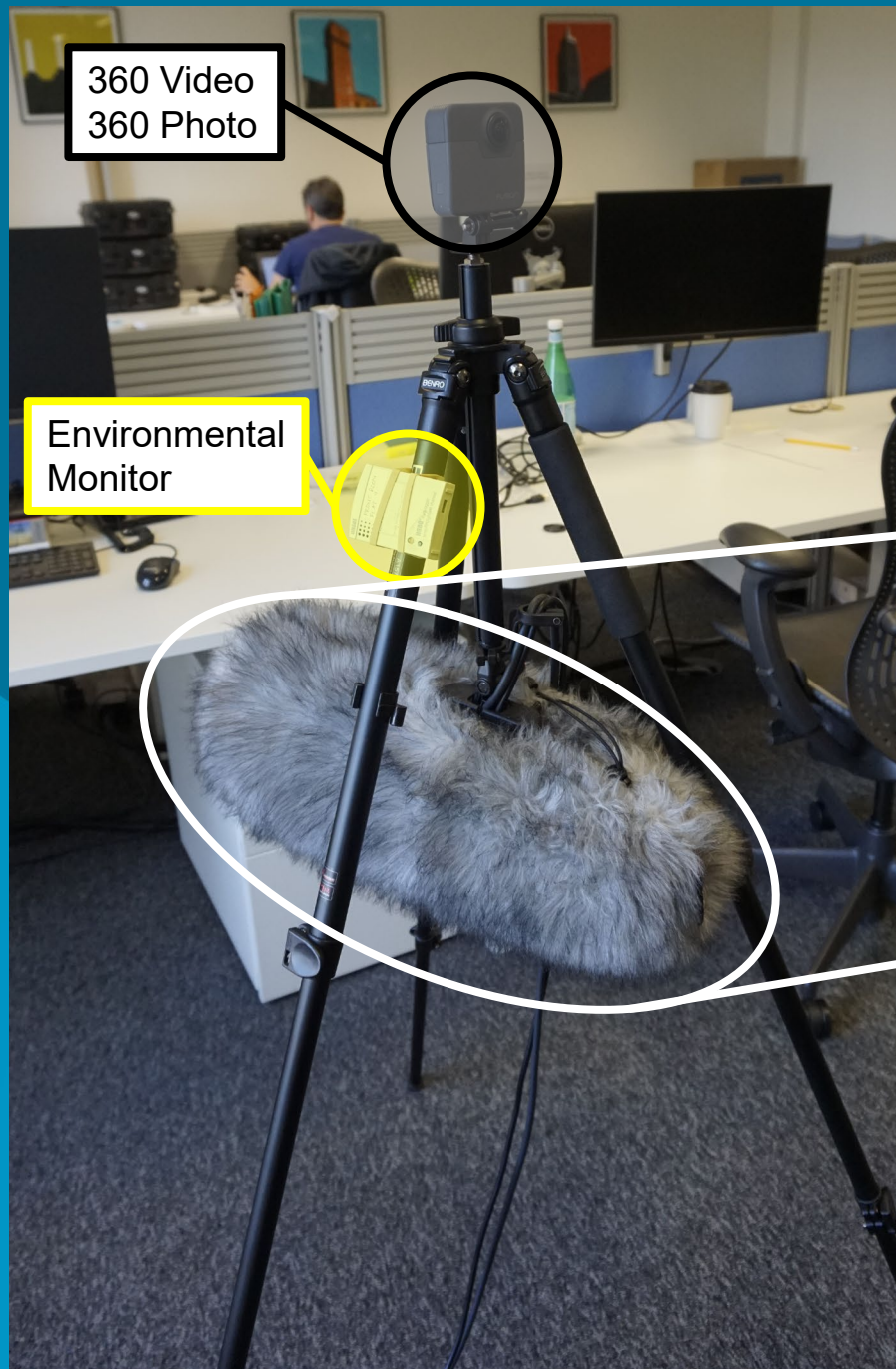


Carrying out the Survey



1. Each survey includes:
2. Questionnaires (min. 100 per location)
3. Binaural audio recording for each group of respondents
4. Continuous SLM measurements
5. Continuous environmental measurements
6. 360° Photos
7. 360° Video (for lab-based VR)
8. Spatial Audio (for lab-based VR)

Equipment used



Equipment used



NTI AUDIO XL2 SOUND LEVEL METER

SQOBOLD HEADPHONES

HOBO TEMPERATURE/RG/LIGHT LOGGER

SQOBOLD BINAURAL RECORDING SYSTEM

GoPro 360 CAMERA AND CALIBRATOR

MIX-PRO 10 FOR AMBISONIC MICROPHONE

TABLETS AND BATTERIES

SSID Protocol – Questionnaire Stage

- Based on ISO/TS 12913-2:2018 Method A
- Focused on collecting a large-scale database – a large and diverse training set is necessary for building a machine learning prediction model
- Enables simultaneous acoustic and environmental data collection
- Organises the location into multiple levels of factors which may influence perception:
 1. Individual – level
 2. Session – level
 3. Location - level

Level of Information	Example Label					Factors Measured at This Level
Location	RegentsParkJapan					GPS, Architectural typology, visual openness, etc.
SessionID	RegentsParkJapan1		RegentsParkJapan2			SLM, session notes, ENV
GroupID	RPJ101	RPJ102	...	RPJ201	...	BIN, PIC
Questionnaire	1, 2, 3	4, 5	...	25, 26	...	QUE, Start & End time

Perceived Affective Quality (PAQs)

For each of the 8 scales below, to what extent do you agree or disagree that the present surrounding sound environment is...

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
Pleasant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Chaotic	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Vibrant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Uneventful	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Calm	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Annoying	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Eventful	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Monotonous	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Sound Sources

To what extent do you presently hear the following four types of sounds?

	Not at all	A little	Moderately	A lot	Dominates completely
Traffic noise (e.g. cars, buses, trains, airplanes)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other noise (e.g. sirens, construction, industry, loading of goods)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sounds from human beings (e.g. conversation, laughter, children at play, footsteps)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Natural sounds (e.g. singing birds, flowing water, wind in vegetation)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Overall soundscape

Overall, how would you describe the present surrounding sound environment?

- ☐ Very good
- ☐ Good
- ☐ Neither bad nor good
- ☐ Bad
- ☐ Very bad

Overall, to what extent is the present surrounding sound environment appropriate to the present place?

- ☐ Not at all
- ☐ Slightly
- ☐ Moderately
- ☐ Very
- ☐ Perfectly

How loud would you say the sound environment is?

- ☐ Not at all
- ☐ Slightly
- ☐ Moderately
- ☐ Very
- ☐ Extremely

Case Study Sites

- Over 30 sites surveyed so far in the UK, Italy, Spain, Netherlands and China covering a variety of acoustic environments and non-auditory factors
- 3000+ individual responses collected so far



Objective Acoustic Features (from Binaural recordings)

Acoustic (dB-based) features

- L_{eq} , L_{Aeq} , L_{ceq} , **etc.**
Equivalent energy level
- $L_{Ceq} - L_{Aeq}$
Low frequency content
- L_N (L_5 , L_{10} , L_{50} , L_{90} , L_{95})
Statistical breakdown of L_{eq}
- $L_{10} - L_{90}$
Degree of variation, or difference between foreground and background level
- **Octave band levels / Spectral Centroid**
Spectral content

• *Psychoacoustic features*

- **Loudness (N , sones)**
 - Perceived loudness
- **Sharpness (S , acum)**
 - Spectral content
- **Fluctuation Strength (vacil)**
 - Amplitude modulation, up to 4 Hz
- **Roughness (R , asper)**
 - Amplitude modulation, 4 – 70 Hz
- **Tonality (T)**
 - Perceived presence of a tonal component

Reproduction of the Soundscape

A 12+1 speaker 1st order ambisonic playback system built within a dedicated lab at UCL

Paired with a VR headset, this enables us to fully reproduce the audio visual soundscape within the lab



acoustic glue
aster 9 mm
sorber / diffuser pannel / void +180 mm
side air

inside air

A_A

E_E

G.12

WAITING AREA /
SHARED SPACE
22,4 m²

WALL A

CEILING

WALL B

G.41

LISTENING
ROOM
17,7 m²

FLOOR_A

+0,00

+0,18

SERVICES

CONTROL
ROOM AND
STORAGE
2,7 m²

storage
compartment

G.14

one-way
window
P = 80 cm

FLOOR_B

H

WALL B

H

G.12

CONTROL
ROOM AND
STORAGE
3,58 m²

sockets for powering the
computer, outboard,
speakers and the wired
internet connection

one-way
window
P = 80 cm

detachable or
foldable ramp
6%

WAITING AREA /
SHARED SPACE
22,4 m²

+0,00

WALL A

LISTENING
ROOM
17,7 m²

+0,18

G.41

currently
50 dB

WALL B

G.14

truss/pipe grid (ø250mm) mounted
speaker system + truss mounted lights
(remotely controlled, with dimmer)

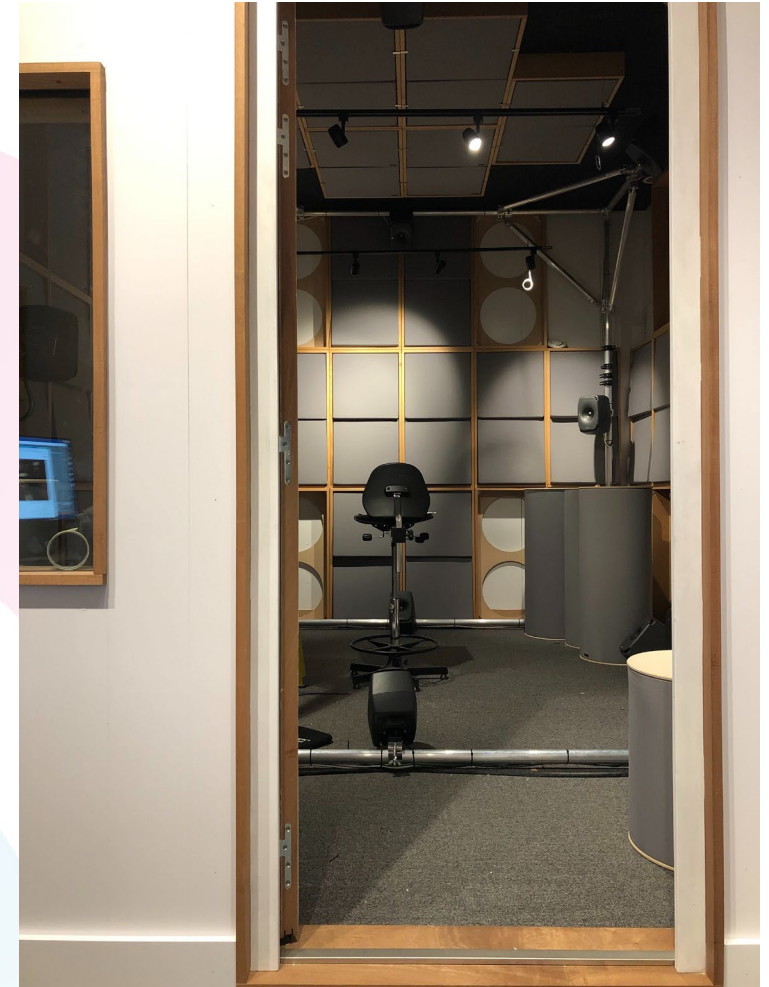
G.14

FLOOR_A

Current challenges with reproduction

COVID ruins everything

- Online surveys based on binaural recordings
- Hope to be back in the ambisonic lab with participants soon!



Thank you for your attention!

For more detailed information on the protocol, see:
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For more on me and my work, visit:

Google Scholar

Website: <https://andrew-mitchell.netlify.app/>

And my podcast: <https://www.justnoisepod.com/>

