

Soundscapy

A Python Package for Soundscape Assessment and Analysis

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Introduction

- Soundscape: A holistic approach to understanding and assessing acoustic environments

[PD ISO/TS 12913-3:2019](#)

Soundscape addresses these challenges through:



BSI Standards Publication

Acoustics — Soundscape

Part 3: Data analysis

Figure 1: ISO 12913-3 recommendations for soundscape analysis

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- Alignment with ISO 12913-3 guidelines for consistency (including upcoming revisions)
- Facilitating reproducible and standardized analysis workflows
- Bridging the gap between theoretical soundscape concepts and practical applications
- Enabling large-scale soundscape studies with efficient data processing

[PD ISO/TS 12913-3:2019](#)



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Figure 1: ISO 12913-3 recommendations for soundscape analysis

Soundscapy: Origins and Purpose

- Developed as part of the Soundscape Indices (SSID) project, an ERC Horizon 2020 Grant
- Built upon the SSID Protocol, a standardized method for *in situ* soundscape data collection
- Builds upon the extensive International Soundscape Database (ISD) and other ISO 12913-2 datasets

Key features and innovations:

- Advanced visualization using distributional methods for nuanced soundscape representation
- Comprehensive psychoacoustic and acoustic analysis capabilities for binaural recordings
- Optimized for efficient processing of large-scale soundscape datasets
- Ensures consistency with ISO 12913-3 guidelines throughout the analysis pipeline



Simple installation and intuitive usage

```
pip install soundscape
```

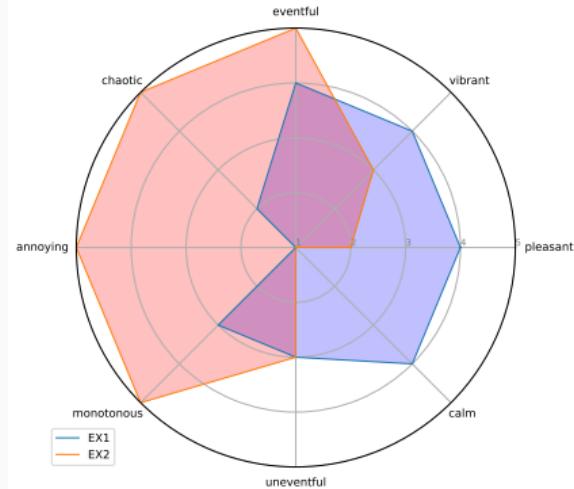
```
import soundscape as sspy
```

Soundscape Circumplex Model

- Proposed by Axelsson, Nilsson, and Berglund (2010)
- Comprises two orthogonal dimensions that capture key aspects of soundscape perception:
 - Pleasant-Annoying (x-axis)
 - Eventful-Uneventful (y-axis)
- Eight perceptual scales
- Officially adopted in ISO/TS 12913-2, quickly becoming the dominant soundscape perception assessment method^a
- Serves as the cornerstone for Soundscapy's analytical approach and visualisations

^aAletta and Torresin (2023)

```
from soundscapy.plotting import likert
likert.paq_radar_plot(sample_transform)
```



ISO Coordinates Calculation

- Transforms 8 PAQ responses into 2D coordinates
- Implements improved equations from ISO 12913-3 upcoming revisions
- Offers flexible input ranges (e.g., 1-5, 0-100) to accommodate various survey designs
- Supports different angle configurations for various survey translations^a

$$P_{ISO} = \frac{1}{\lambda_{Pl}} \sum_{i=1}^8 \cos \theta_i \cdot \sigma_i \quad (1)$$

$$E_{ISO} = \frac{1}{\lambda_{Pl}} \sum_{i=1}^8 \sin \theta_i \cdot \sigma_i \quad (2)$$

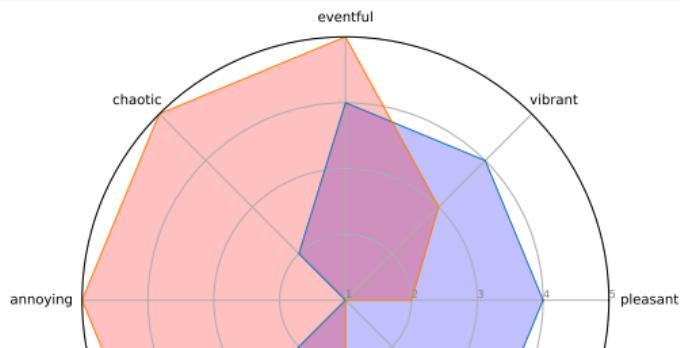
```
# Load data from the ISD
data = sspy.isd.load()

# Apply built-in data quality checks
data, excl_data = sspy.isd.validate(data, allow_paq_na=False)

# Calculate the ISO Coordinates
data = sspy.surveys.add_iso_coords(data)
```

	PAQ1	PAQ2	PAQ3	PAQ4	PAQ5	PAQ6	P
0	2.0	4.0	2.0	1.0	2.0	2.0	4.0
1	2.0	4.0	4.0	4.0	4.0	4.0	1.0
2	5.0	3.0	3.0	1.0	2.0	1.0	3.0
3	5.0	3.0	3.0	1.0	2.0	2.0	3.0
4	5.0	3.0	3.0	2.0	2.0	3.0	3.0

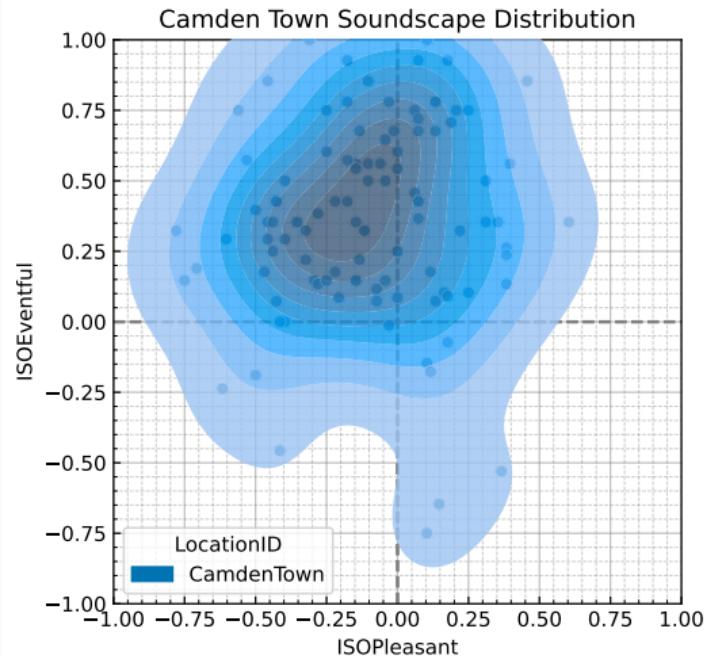
^aAletta et al. (2024)



Distribution-based Analysis

- Developed by Mitchell, Aletta, and Kang (2022)
- Represents the collective perception of a soundscape as a distribution, using kernel density estimation
- Key Benefits:
 - Visualizes central tendency, dispersion, and skewness of perceptions
 - Illustrates the shape and extent of soundscape perception in circumplex space
 - Allows for statistical comparisons between different soundscapes or groups
- Additional features:
 - Calculation of percentiles and other statistical measures
 - Multiple visualization options (both Seaborn and Plotly backends available)

```
sspy.plotting.density_plot(  
    sspy.isd.select_location_ids(data, "CamdenTown"),  
    title="Camden Town Soundscape Distribution",  
    hue="LocationID",  
    incl_scatter=True  
)
```



```
1 sspy.plotting.density_plot(  
2     sspy.isd.select_location_ids(data, ("CamdenTown", "PancrasLock")),
```

Databases Integration

- International Soundscape Database (ISD)^a
 - 2,706 high-quality, real-world binaural recordings
 - 3,589 *in situ* survey responses
 - Data from 6 cities across Europe and China
- Soundscape Attributes Translation Project (SATP)^b
 - 19,089 responses
 - 708 participants
 - 19 languages
- ARAUS (Affective Responsees to Augmented Urban Soundscapes)^c
 - Currently under development
 - Large-scale lab-based dataset of augmented soundscapes

^aMitchell et al. (2021)

^bOberman et al. (2024)

^cOoi et al. (2023)

```
# Load ISD data
isd_data = sspy.isd.load()

# Load SATP data
import soundscape.databases.satp as satp
satp_data = satp.load_zendoo()

print(f"ISD shape: {isd_data.shape}")
print(f"SATP shape: {satp_data.shape}")

sspy.isd.soundscape_describe(isd_data).head(5)
```

ISD shape: (3589, 142)

SATP shape: (17441, 16)

	count	ISO Pleasant	ISO Eventful	pl
CarloV	126	0.518	-0.012	0.
SanMarco	99	0.221	0.373	0.
PlazaBibRambla	24	0.463	-0.023	0.
CamdenTown	105	-0.103	0.364	0.
EustonTap	100	-0.211	0.190	0.

Psychoacoustic Analysis

Integration with multiple libraries:

- Python Acoustics: For standard acoustic metrics
- scikit-maad: Advanced ecological soundscape analysis
- MoSQUITo: Psychoacoustics metrics

Wide range of metrics:

- SPL (L_{Zeq} , L_{Aeq} , L_{Ceq})
- Loudness (N)
- Sharpness (S)
- Roughness (R)
- Bioacoustic Indices
- Many more...

Key advantages:

- Completely free, open license, and open source
- Adherence to ISO and other relevant standards
- Optimized for binaural recordings
- Consistent calculation methods across studies
- Extensible framework for adding new metrics

```
from soundscape.audio.analysis_settings import MetricSettings
from soundscape.audio import Binaural

b = Binaural.from_wav("data/CT101.wav")

laeq_settings = MetricSettings(
    run = True,
    statistics = (5, 50, 'avg', 'max'),
    label="LAeq",
)

b.pyacoustics_metric('LAeq', metric_settings=laeq_settings).round(2)
```

Recording

CT101

```
b.mosqito_metric('sharpness_din_perseg').round(2)
```

Recording

CT101

Batch Processing and Performance

- **Unified Output Format:** Ensures consistency across datasets, simplifying analysis.
 - **Parallel Processing:** Leverages multi-core CPUs for efficient computation.
 - **Reproducible Analysis:** Shareable plain-text analysis configuration and documentation.

Performance Example:

- 20 recordings (10 min 41 sec total)
 - Serial processing: ~60 minutes
 - Parallel processing: 8.5 minutes
 - Speed-up factor: 7x

```
from soundscape.audio import AudioAnalysis
2
3 wav_folder = Path("data")
4
5 # Initialize AudioAnalysis with default settings
6 analysis = AudioAnalysis()
7
8 # Analyse a folder of recordings
9 folder_results = analysis.analyze_folder(
10     wav_folder,
11     calibration_file="data/Levels.json"
12 )
13
14 # Print results
15 folder_results.head()
```

Customization and Flexibility

- **Reproducible Analysis:** YAML-based configs ensure consistent, replicable results.
- **Version Control Friendly:** Easily track, share, and collaborate on configurations.
- **Data Science Integration:**
 - Works with pandas for data manipulation
 - Compatible with matplotlib/seaborn and plotly for visualizations
 - Leverages popular Python libraries
- **Extensible Architecture:**
 - Allows addition of new metrics and methods
 - Adaptable to diverse research requirements
 - Potential for community-driven improvements

```
# Customize analysis settings
new_config = {
    "MoSITo": {
        "loudness_zwtv": {
            "statistics": ("avg", 5, 50),
            "func_args": {"field_type": "diffuse"}
        }
    }
}

analysis.update_config(new_config)
analysis.save_config("updated_config.yaml")
```

```
1 # Settings file for batch acoustic analysis.
2 # This file configures which metrics are calculated and how they are processed.
3
4 version: "1.0"
5
6 # Python Acoustics Library Settings
7 # Supported metrics: LAeq, LZeq, LCeq, SEL
8 # Mitchell, 23/08/2024, 19:15 • refactored binaural analysis functions
9 PythonAcoustics:
10     # A-weighted equivalent continuous sound level
11     LAeq:
12         run: true # Set to false to skip this metric
13         main: 'avg' # Main statistic to calculate
14         statistics: [5, 10, 50, 90, 95, 'avg', 'min', 'max', 'kurt', 'skew'] # List of statistics to calculate
15         channel: ['Left', 'Right'] # Channels to analyze
16         label: 'LAeq' # Label for the metric in output
17         func_args: # Additional arguments for the metric function
18             time: 0.125 # Time interval for calculation (seconds)
19             method: "average" # Method for calculating LAeq
20
21     # Z-weighted (unweighted) equivalent continuous sound level
22     LZeq:
23         run: true
24         main: 'avg'
25         statistics: [5, 10, 50, 90, 95, 'min', 'max', 'kurt', 'skew']
26         channel: ['Left', 'Right']
27         label: 'LZeq'
28         func_args:
29             time: 0.125
30             method: "average"
31
32     # C-weighted equivalent continuous sound level
33     LCeq:
34         run: true
35         main: 'avg'
36         statistics: [5, 10, 50, 90, 95, 'min', 'max', 'kurt', 'skew']
37         channel: ['Left', 'Right']
```

Package Documentation

■ Comprehensive Documentation:

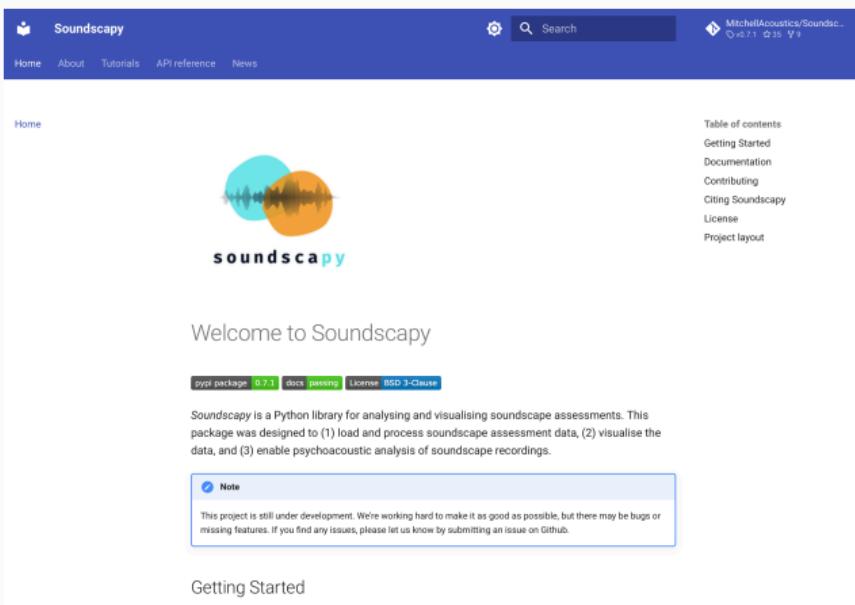
- Installation guide
- Quickstart tutorials
- API reference
- Example notebooks

■ GitHub Repository:

- Open-source code
- Issue tracking
- Contribution guidelines

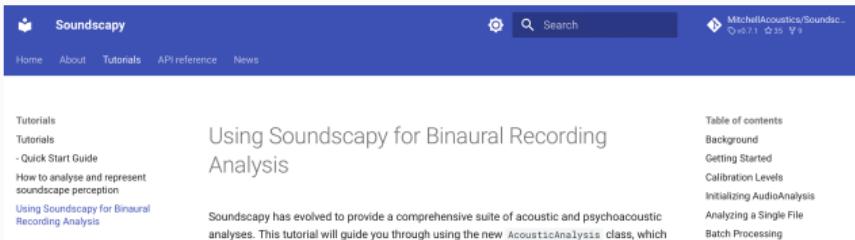
■ Regular Updates:

- Version changelog
- Deprecation notices
- New feature announcements



The screenshot shows the Soundscapy documentation homepage. At the top, there's a dark blue header with the Soundscapy logo, a search bar, and navigation links for Home, About, Tutorials, API reference, and News. To the right of the header is a sidebar with links to Table of contents, Getting Started, Documentation, Contributing, Citing Soundscapy, License, and Project layout. The main content area features a large logo with two overlapping circles (one teal, one orange) and the word "soundscapy" below it. Below the logo is a "Welcome to Soundscapy" message. A "Note" box contains a message about the project being under development. Further down, there's a "Getting Started" section.

Figure 2: Soundscapy Documentation Homepage



This screenshot shows the "Tutorials" page of the Soundscapy documentation. The layout is identical to the homepage, with the Soundscapy logo, search bar, and navigation links at the top. The sidebar on the right includes a "Table of contents" link. The main content area on the left lists several tutorial topics: "Tutorials", "Quick Start Guide", "How to analyse and represent soundscape perception", and "Using Soundscapy for Binaural Recording Analysis". The right side of the page features a large title "Using Soundscapy for Binaural Recording Analysis" and a detailed description of the tutorial's purpose.

Future Work: Predictive Models¹

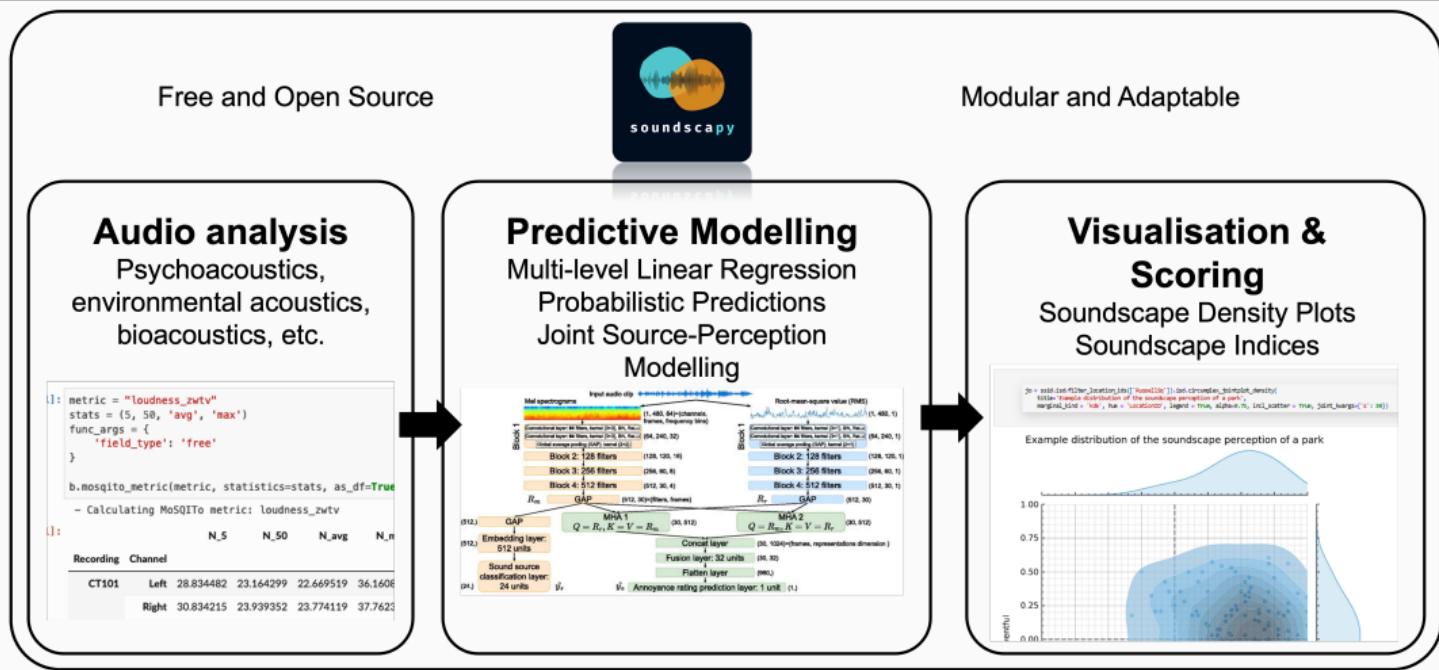


Figure 4: Modular Framework

- **Pretrained Models Integration:**
 - Predict soundscape perception from acoustic features
 - Multiple model support for comparison

- **Design Optimization:**
 - Predict impact of soundscape interventions
 - Assist in urban planning decisions

¹Hou et al. (2024)

Future Work: Soundscape Perception Indices (SPI)²

- Single Index Calculation:
 - Simplify complex soundscape data
 - Enable quick comparisons between locations
- Standardized Reporting:
 - Facilitate communication with stakeholders
 - Support policy-making processes
- Customizable Weighting:
 - Adapt to different cultural contexts
 - Account for varying research priorities
- Applications:
 - Urban planning and design optimization
 - Environmental quality assessment
 - Cross-cultural soundscape studies

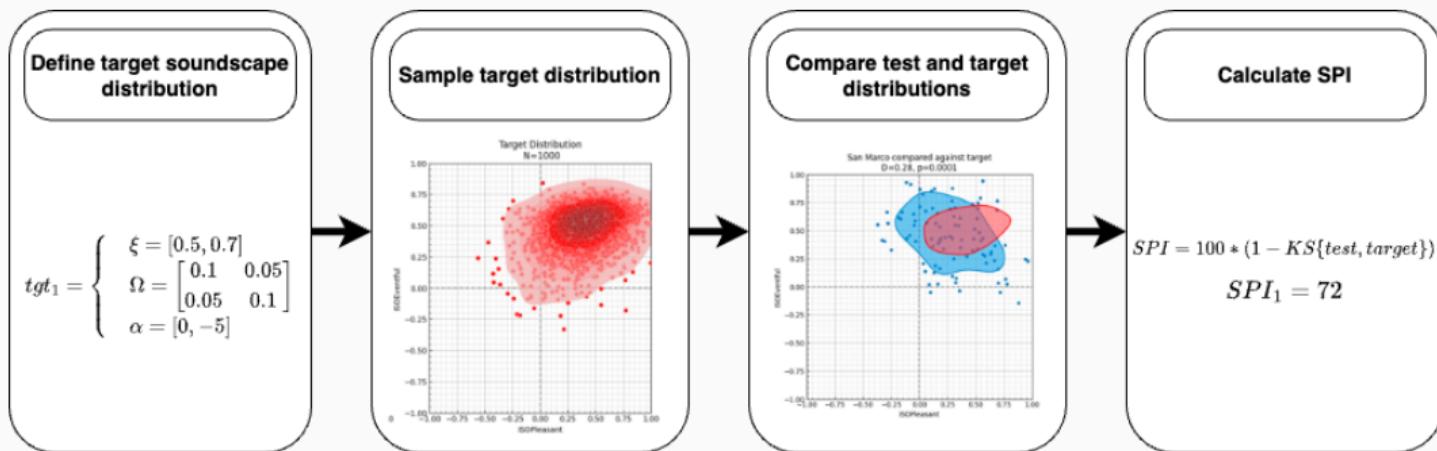


Figure 5: SPI Calculation Framework

²Mitchell et al. (2024)

Conclusion

- **Standardized Analysis:** Consistent with ISO 12913-3 guidelines
- **User-Friendly:** Easy-to-use Python package for researchers and practitioners
- **Powerful Tools:**
 - Distribution-based visualization
 - Comprehensive psychoacoustic analysis
 - Efficient batch processing
- **Future-Ready:**
 - Ongoing development for predictive models
 - SPI for simplified soundscape assessment
- **Get Involved:**
 - GitHub: github.com/MitchellAcoustics/Soundscape
 - Docs: soundscapy.readthedocs.io
 - PyPI: `pip install soundscapy`



References

- Aletta, Francesco, Andrew Mitchell, Tin Oberman, Jian Kang, Sara Khelil, Tallal Abdel Karim Bouzir, Djihed Berkouk, et al. 2024. "Soundscape Descriptors in Eighteen Languages: Translation and Validation Through Listening Experiments." *Applied Acoustics* 224 (September): 110109. <https://doi.org/10.1016/j.apacoust.2024.110109>.
- Aletta, Francesco, and Simone Torresin. 2023. "Adoption of ISO/TS 12913-2:2018 Protocols for Data Collection from Individuals in Soundscape Studies: An Overview of the Literature." *Current Pollution Reports*, October. <https://doi.org/10.1007/s40726-023-00283-6>.
- Axelsson, Östen, Mats E. Nilsson, and Birgitta Berglund. 2010. "A principal components model of soundscape perception." *The Journal of the Acoustical Society of America* 128 (5): 2836–46. <https://doi.org/10.1121/1.3493436>.
- Hou, Yuanbo, Qiaoqiao Ren, Andrew Mitchell, Wenwu Wang, Jian Kang, Tony Belpaeme, and Dick Botteldooren. 2024. "Soundscape Captioning Using Sound Affective Quality Network and Large Language Model." <https://doi.org/10.48550/ARXIV.2406.05914>.
- Mitchell, Andrew, Francesco Aletta, and Jian Kang. 2022. "How to Analyse and Represent Quantitative Soundscape Data." *JASA Express Letters* 2 (3): 037201. <https://doi.org/10.1121/10.0009794>

Also check out my other package for even more advanced circumplex analysis, currently under development!



This presentation is available online at
<https://mitchellacoustics.quarto.pub/interno2024-soundscapey-pres>