DOI: 10.61782/fa.2023.0998

forum acusticum 2023

RELATING INDIVIDUAL SOUNDSCAPE ATTRIBUTES WITH ISOVIST SPACE SYNTAX INDICES

Josep Llorca-Bofí[1,2*], **Jonas Heck**[1], **Michael Vorländer**[1]
[1] Institute for Hearing Technology and Acoustics, RWTH Aachen University, Aachen, Germany
[2] Department of Architectural Representation, Universitat Politècnica de Catalunya, Barcelona, Spain

ABSTRACT

Within the research project "Person-focused Analysis of Architectural Design", it is a goal to correlate the individual soundscape attributes with objective urban space indicators. This contribution will present, in particular, a comparative analysis with the established Space Syntax indices, and more specifically, with isovists. These indices were developed during the last decades to characterize urban morphology and predict human perception in spatial contexts. However, not a big amount of research provides conclusions on urban perception situations where sound matters. By correlating individual vocabulary profiles and isovists definitions, we aim to quantify the prediction accuracy of such indicators.

Keywords: *soundscape, space syntax, acoustics, visibility*.

1. INTRODUCTION

In 1979, the architect Michael Benedikt defined the term isovist, as the volume of space visible from a given point in space, together, with a specification of the location of that point. Isovists are naturally three-dimensional, but they have been extensively studied in two dimensions in the field of space syntax [1]. The isovist provides a mathematical basis for analyzing and shaping architectural space and form. Significantly, isovists can also be used for investigating, and even predicting, human behavioral and cognitive responses to buildings [2].

In this framework, most of the isovist research has been mainly related with visual cues and correlations with social and people's behaviour in spaces, covering topics like public space and crime prediction in urban areas or sense of safety or community formations, among others [3]. However, the relation between these definitions and the perception of the acoustic environment has not been investigated in detail.

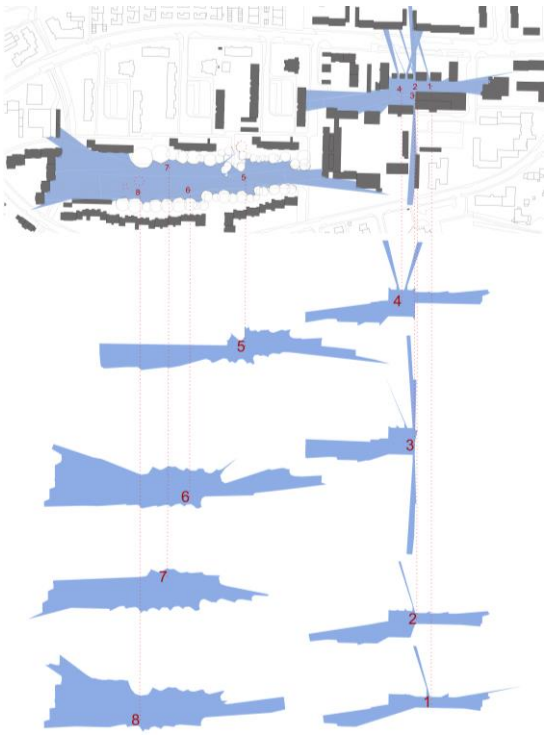

Figure 1: Plan of the market place (positions 1 to 4) and the park (positions 5 to 8), at Driescher Hof, Aachen. The isovist polygons for each position are displayed below.

[*] ***Corresponding author***: josep.llorca@akustik.rwth-aachen.de

For this reason, this pilot study aims to correlate auditory and visual individual attributes with space syntax indices from isovist definitions. The hypothesis, following existing literature is: attributes describing audiovisual or visual features, correlate better with Space Syntax indices than clusters from auditory attributes separately [3]. However, results show different tendencies, as we will see.

The individual attributes are clustered according to similar ratings from different people in five different ways, namely: 1) Auditory, 1) Visual, 3) Audiovisual and their combinations of 4) Auditory+Visual and 5) Auditory+Visual+Audiovisual. Five clusters from each combination have been extracted and the correlation with a total of 17 isovist definitions calculated and discussed.

2. METHODS AND MATERIALS

In this section, the methods used to investigate both independent variables (individual soundscape attributes and isovist space syntax indices) are going to be described. Section 2.1 will describe how the individual soundscape attributes were collected. Section 2.2 will describe how the isovist analysis has been performed. Finally, section 2.3 describes the statistical analysis to uncover relationships between both fields.

2.1 Individual soundscape attributes

The setup consists of 8 recorded positions (Figure 1). The audio information is recorded in Ambisonics B format, using the Zoom H3-VR microphone. The level of the microphone was adapted for each scene according to the dynamic range recorded at each environment. The video information was recorded in 360º video format with a resolution of 7680 x 4320 pixels. Both formats are reproduced using the Youtube 360 audiovisual platform, thus allowing the participants to perform the test at their own homes. The recorded length for each stimulus is approximately 30 seconds. The recorded acoustic salient events at each position is described in previous work [4].

2.1.1 Participants and questionnaire

12 participants performed the test, aged between 20 and 35. All are students or with academic background. Every participant was provided with the same reproduction lists in Youtube and an online questionnaire to develop and rate the vocabularies, as explained in the previous study [5].

The questionnaire follows the Individual Vocabulary Profiling (IVP) method. IVP is a descriptive analysis test, in which the assessors perform individual word elicitation by listening and viewing to the stimuli and provide words to describe how they perceive the space quality and the differences between the stimuli. Assessors were asked to provide 4 to 8 words to describe their perception. The assumptions behind this approach considers that assessors will fundamentally perceive the stimuli in a similar manner, but may use different adjectives to express their perception. For this reason, clustering of the attributes is a crucial phase. Five group of clusters according to the perceptive dimensions are finally used as datasets. (Figure 2):

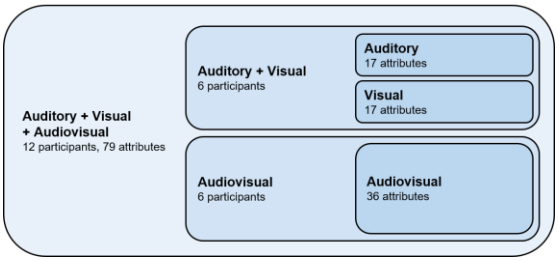

Figure 2: Dataset organization diagram. (A) Auditory, (V) Visual, (A+V) Auditory+Visual, (AV) Audiovisual, (A+V+AV) Auditory + Visual+Audiovisual. Five clusters are built for each dataset.

2.2 Isovist space syntax indices

The following isovist measure defintions have been calculated for each of the 8 urban points:

- Area, visible area
- Distance-weighted area
- Perimeter
- Compactness, property relative to a circle [6].
- Circularity, comparison of the area to the perimeter of the isovist [7].
- Convex deficiency: difference of the areas of the convex hull and the shape divided by the hull area [6].
- Occlusivity: the proportion of edges of an isovist that are not physically defined (isovists.org) [8]. The greater the level of occlusion, the greater the sense of mystery [7].
- Minimum Radial
- Maximum Radial

- Mean Radial
- Standard Deviation, of the length of all radials of an isovist.
- Variance
- Skewness, third moment about the mean of the radials. It relies on a similar formula to variance, although the radial difference calculations are cubed [2].
- Dispersion, equivalent to skewness [9].
- Elongation, from a square room (1:1) up to a corridor (1:9) [7].
- Drift Magnitude, distance from the subject point to the center of gravity of its isovist.
- Drift Angle, the angle between the direction facing the occupant and the mass centre of an isovist polygon [10].

The calculation has been performed using the DeCodingSpaces Toolbox for Grasshopper [11]. All metrics have been evaluated using a maximum radial of 200 meters.

2.3 Statistical analysis: correlation

Between the set of values from the individual soundscape attributes and the isovist definitions, a Spearman correlation analysis has been performed. The low number of observations (8 locations in our case) suggests the use of this type of correlation analysis, rather than a Pearson correlation, as Kuusinen et al. support [12].

3. RESULTS AND DISCUSSION

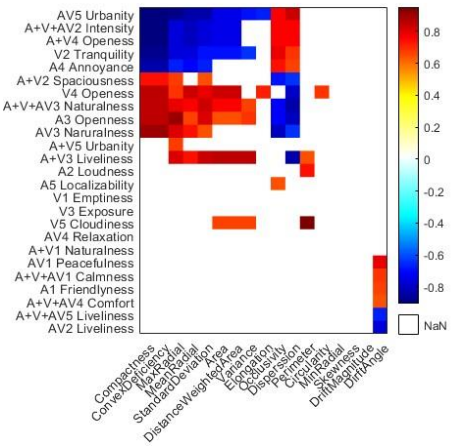

Figure 3: Spearman correlation between individual soundscape attribute clusters (vertical axis, enumerated from 1 to 5 for each dataset), and space syntax isovist measures (horizontal axis). Red and blue values show a high positive or negative correlation values, after filtering out items with lower p-value than 0,1.

High correlation values can be found between pairs of variables in Figure 3. It is worth noting that correlation values are mostly high (>0.7), whether positive or negative.

It is interesting to see that several clusters in all vocabulary variables correlate well with specific isovist definitions. In particular, at least two clusters from each vocabulary combination correlates with several isovist definitions. In the following description, a detailed discussion over each isovist definition is given.

3.1 Auditory attributes correlating with several isovist definitions at the same time

- **Sound intensity level** (A+V+SV2), **unevenness** and human voice and birds **loudness** (A+V2), **level** of nature, **relief, continuity, annoyance** and **sound intensity** (A4) correlate with *Compactness*, *Convex Deficiency*, *Max Radial* and *Standard Deviation*, *Occlusivity* and *Dispersion*
- In addition, **Annoyance, Sound intensity** and **level** (A+V+AV2) also correlate with area and correlate additionally with *Area* and *Distance Weighted Area* and *Variance*.
- In addition, **Openess** (A3 and A+V4), **Naturalness** (AV3), **feeling of relaxation** (A+V+AV3), **loudness** and **sound mess** (A+V3) also correlate positively with *Variance*.

3.2 Auditory attributes correlating only with one or no isovist definitions.

- **Friendliness** (A1), **relaxation**, **calmness**, **ambience**, **vividness** (AV4), **repeatability**, **clarity in terms of annoyance**, and **source naturalness** (A+V1) are not correlating;
- The purely Auditory attribute cluster containing **Loudness**, **sound messs**, **sharpness**, **metallic** (A2) only correlates with *Perimeter*; and **annoyance**, **localizability**, **human voices**, **loudness** and **birds chirping** (A5) only correlates with *Occlusivity*.
- Finally, *Drift Angle* correlates with several Auditory attributes: AV1 (**peacefulness**),

A+V+AV1 (peacefulness, calmness), A1 (friendlyness) and A+V+AV5 (liveliness, loudness, sound mess, stimulating, loudness, noisiness, annoyance); and AV2 (joyfulness, liveliness, stimulating, loudness, and annoyance).

4. DISCUSSION

One first point to discuss is the flipped positive and negative correlation effect. Interestingly enough, three of the six first clusters correlating positively with the first 9 isovist definitions, while the other three negatively correlate with them. The inverse happens for the two next isovist defintions (*Occlusivity* and *Disperssion*). The interleaving of positive and negative correlations suggest that some attributes have been treated with flipped scales, depending on their meaning. Since the values for the study have been taken from the participants directly, further investigations on the direction of the scales would be necessary.

Another point to discuss is the appropriateness of some correlations according to the meaning of the audio attributes. If we take a close look to them using informed knowledge, it can be discussed that the following correlations make sense:

- **Loudness** correlates with *Compactness* and *Convex deficiency*, which are metrics to quantify how close to a circle is the isovist perimeter around the viewer. In the assumption of having equally absorptive facades around the receiver, this correlation would make sense, since the acoustic energy would focalize on the receiver point.
- **Annoyance** correlates with *Area*. Smaller isovist areas would amplify sound, since the energy kept in a smaller environment is bigger than the energy spread around the bigger space.
- **Openness** correlates with *Radial variance*. This correlation suggests that people perceive more acoustically open spaces when the perimeter around them varies greatly around them.

5. CONCLUSIONS

In this pilot study, we investigated the correlation between individual soundscape attributes with isovist definitions. The hypothesis of this study is that "Visual attributes correlate better and with more isovist definitions than Auditory attributes". The results show that this is not the case: the same number of clusters of purely Visual and Auditory attributes correlate well (2 clusters from each: A3, A4, V2 and V4) as well as for Audiovisual attributes (AV3, AV5). In summary, Auditory attributes dealing with **loudness**, **level** and **annoyance** correlate, and not the ones relating with feelings of **relaxation**, **calmness** and **naturalness**. The best correlating isovist definitions with Auditory attributes are *Compactness*, *Convex Deficiency*, *Max* and *Mean Radial*, *Standard Deviation*, *Occlusivity, Disperssion* and *Drift Angle*. They do not correlate, though, with *Perimeter*, *Circularity*, *Min Radial*, *Skewness* and *Drift Magnitude*. These definitons might help architects and urban planners, since they might provide a prediction of how people would perceive those urban spaces in terms of loudness, level and annoyance. This is a valuable output in planning phases.

Further investigations on the direction of scales need to be taken into account, and a bigger dataset will be needed to get extract stronger statistical conclusions.

6. ACKNOWLEDGMENTS

This research was funded by the Federal Ministry of Education and Research (BMBF), the Federal Ministry for Economic Affairs and Climate Action (BMWi) and the Ministry of Culture and Science of the German State of North Rhine-Westphalia (MKW) under the Excellence Strategy of the Federal Government and the Länder.

7. REFERENCES

[1] Benedikt, M. L. (1979). To take hold of space: isovists and isovist fields. Environment and Planning B: *Urban analytics and City Science*. 6, 1. Doi: https://doi.org/10.1068/b060047

[2] Ostwald, M. J., Dawes, M. J. (2018). Isovists: Spatio-Visual Mathematics in Architecture. In: Sriraman, B. (eds) Handbook of the Mathematics of the Arts and Sciences. Springer, Cham. doi: https://doi.org/10.1007/978-3-319-70658-0_5-1

[3] Hillier, B., Hanson J. (2009) The Social Logic of Space. Cambridge Universeity Press. Doi: https://doi.org/10.1017/CBO9780511597237

[4] Llorca-Bofí, J., Sezer, C., Heck, J., Vorländer, M. (2022). Unfolding urban vocabularies - Audio-visual description of public spaces. *DAGA 2022 – 48. Jahrestagung für Akustik. Stuttgart*. Url: https://www.researchgate.net/publication/359932289_Unfolding_urban_vocabularies_-Audio-

visual_description_of_public_spaces (Accessed: 13.03.2023)

[5] Llorca-Bofí, J., Heck, J., Vorländer, M. (2023). Within-subject Exploration of Individual Vocabulary Profiles from Urban Soundscape Variations. *DAGA 2022 – 48. Jahrestagung für Akustik. Hamburg.* Url: https://pub.dega-akustik.de/DAGA_2023/data/index.html

[6] Stamps, A. E. (2005). Isovists, enclosure, and permeability theory. *Environment and Planning B: Planning and Design,* 32, 735-762. Doi: https://journals.sagepub.com/doi/pdf/10.1068/b31138

[7] Stamps, A. E. (2011). Effects of Area, Height, Elongation, and Color on Perceived Spaciousness. Environment and Behavior, 43(2) 252-273. Doi: https://journals.sagepub.com/doi/pdf/10.1177/0013916509354696

[8] https://isovists.org/ (Accessed 04.05.2023)

[9] Ostwald, M. J., Dawes, M. J. (2013). Using Isovists to Analysie Architecture. The International journal of the Constructed Environment. 3, 1. Doi: https://doi.org/10.18848/2154-8587%2FCGP%2Fv03i01%2F37373

[10] Xiang, L., Papastefanou, G., NG, E. (2020). Isovist indicators as a means to relieve pedestrian psycho-physiological stressin Hong Kong. Environmentla and Planning B: Urban Analytics and City Science, 48, 4. Doi: https://doi.org/10.18848/2154-8587%2FCGP%2Fv03i01%2F37373

[11] DeCodingSpaces Toolbox for Grasshopper. Avilable at: https://toolbox.decodingspaces.net/ (Accessed 25.04.2023)

[12] Kuusinen, A., Pätynn, J., Tervo, S., Lokki, T. (2013). Relationships between preference ratings, sensory profiles and acoustical measurements in concert halls. *J. Acoust. Soc. Am.* 135 (1). Doi. https://doi.org/10.1121/1.4836335