SIENA Consortium

Sustainable Infrastructure and Evidence for Noise and Air

EVIDENCE REVIEW FOR EFFECTS OF SOUNDPROOFING ON RESIDENTS' MENTAL WELLBEING AND ALTERNATIVE DESIGNS

VOLUME III: Indoor Soundscaping

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1. INDOOR SOUNDSCAPING

1.1. ABOUT THIS SECTION

Under the general research question of 'What are the effects of indoor sound environments on mental health, wellbeing, quality of life, annoyance and sleep?' in the Systematic Review, this section, provides a brief discussion from the perspective of indoor soundscaping, based on the materials in the Systematic Review, after an introduction on soundscape and indoor soundscaping.

1.2. SOUNDSCAPE AND INDOOR SOUNDSCAPING

Soundscape research historically started for outdoor spaces, and then recently the concept has also been expanded to various indoor spaces. Therefore, this section started from an introduction about soundscape, mainly on outdoor spaces, and then moves to indoor soundscaping.

From noise control to soundscape creation[1]

In the late 1960s, pioneering works in soundscape were carried out by Schafer[2] and colleagues.[3] A musician and composer, Schafer's early soundscape work had always been about the relationship between the ear, human beings, sound environments and society. The World Forum for Acoustic Ecology (WFAE) was founded in 1993, with members who shared a common concern with the state of the world soundscape as an ecologically balanced entity. While the WFAE represents a multi-disciplinary spectrum of individuals engaged in the study of the social, cultural, and ecological aspects of the sonic environment, less attention has been paid to the planning, designing, and engineering of the soundscapes of built environments.

In 2002, the publication of the EU Directive Relating to the Assessment and Management of Environmental Noise (END)[4] led to a number of major actions, including preserving quiet areas. However, it was recognised that reducing sound level is not always feasible and cost-effective, and more importantly, will not necessarily lead to improved quality of life,[5] as people's acoustic comfort evaluation is also related to the sound type, the user characteristics and other factors.[6] While it was not clear in the END how to determine those quiet areas, where to go with it, how to use it, or how to incorporate it in design, a step change was needed, by developing a new method to assess sound environment quality. Correspondingly, ISO/TC43/SC1/Working Group 54 was formed to work on 'Perceptual assessment of soundscape quality'. In ISO 12913-1:2014 Acoustics – Soundscape - Part 1: Definition and

[1] Kang, J. Soundscape: Progress in the past 50 years and challenges in the next 50 years. *Proceedings of the 50th International Congress and Exposition on Noise Control Engineering*, Washington, USA, 2021.
[2] Schafer, R.M. *The Tuning of the World*, New York: Knopf, 1977. Reprinted as *Our Sonic Environment and the Soundscape: The Tuning of the World*. Destiny Books, 1994
[3] Southworth, M. The sonic environment of cities. *Environment and Behavior*, **1**, 49-70, 1969.
[4] EU (European Union). *Directive of the European Parliament and of the Council of Relating to the Assessment and Management of Environmental Noise*, 2002.
[5] Kang, J. *Urban Sound Environment*, Taylor & Francis incorporating Spon, London, 2007.
[6] Yang, W. and Kang, J. Acoustic comfort evaluation in urban open public spaces. *Applied Acoustics*, **66**, 211-229, 2005.

conceptual framework, soundscape is defined as the 'acoustic environment as perceived or experienced and/or understood by a person or people, in context'.[7]

In other words, 'soundscape' is different from 'acoustic environment' as it relates to perceptual constructs rather than just physical phenomena. It promotes a holistic approach, regarding sounds as 'resources' rather than just 'wastes' and focuses on "wanted" (preference) rather than just "unwanted" (discomfort) sounds. While soundscape has always been related to many disciplines including acoustics, aesthetics, anthropology, architecture, ecology, ethnology, communication, design, human geography, information, landscape, law, linguistics, literature, media arts, medicine, musicology, noise control engineering, philosophy, pedagogics, psychology, political science, religious studies, sociology, technology and urban planning, with the EU Directive END as a key driver, soundscape creation attracted much attention of many acousticians, engineers, designers and planners, moving from soundscape concept to practice.

The potential impacts of soundscape would include:[8] (1) Health: It can help to provide supportive environments which prevent the degradation of functional health and enhance the engagement in health promoting activities less likely in unpleasant neighbourhoods. (2) Culture: It is important in terms of 'sensing of places', tourism, and conservation. (3) Economy: It can bring prosperity to the economy, e.g., property prices, offset health costs through provision of restorative living spaces, reduce costs caused by anti-social behaviours, and prevent unnecessary noise mitigating actions.

Soundscape activities have since increased significantly, as reflected in the number of publications. There have been increasing special sessions in conferences in the field of acoustics such as Internoise, Euronoise, ICA, ICSV, ICBEN, and Westpac, and also in the field of planning such as AESOP. There has also been increasing national and international research projects, practical projects, as well as networks such as the EU-COST network on Soundscape of European Cities and Landscapes, and the Global Sustainable Soundscape Network GSSN.[9]

Indoor soundscaping

While soundscape studies have traditionally involved urban areas and outdoor spaces, indoor soundscape research has been gaining momentum in recent years to address the perceived acoustic quality of indoor built environments. Similar to the situation for outdoor spaces, for indoor spaces, conventional approaches mainly concentrate on technical indices such as background noise level, level of sound transmission and reverberation, whereas the acoustic comfort, considering different people's needs, in context, has been paid less attention. Indeed, measuring people's perception is essential for the design of high-quality soundscapes. While the ISO 12913 framework was mainly developed based on research and evidence conducted in outdoor settings, the actual definition provided in Part 1 of the ISO does not limit its applicability to outdoor spaces, as it refers to acoustic environments as perceived, experienced and/or understood by a person or people IN CONTEXT, where the acoustic environment and context may be either outdoor or indoor.

[7] International Organization for Standardization. *ISO 12913-1:2014 Acoustics — Soundscape — Part 1: Definition and Conceptual Framework*, Geneva, 2014.
[8] Kang, J., Chourmouziadou, K., Sakantamis, K, Wang, B. and Hao, Y. (ed.) *Soundscape of European Cities and Landscapes*. EU COST, Oxford, 2013
[9] Kang, J. and Aletta, F. The impact and outreach of soundscape research. *Environments,* **5**, 58, 1-10, 2018.

While indoor soundscaping is still a relatively new field, the search terms used in the Systematic Review consider the framework of outdoor soundscapes, including domains of Context, Sound, Noise, Health (wellbeing, mental health, quality of life, annoyance, sleep), Perception & Evaluation of sound or noise, and Non-acoustic factors; and also, considering some specific situations for indoor spaces, such as Sound insulation/treatment. It is expected that those search term domains will cover relevant work in the field of indoor soundscaping.

An indoor soundscaping perspective: What are the effects of indoor sound environments on mental health, wellbeing, quality of life, annoyance and sleep

Core keywords in soundscape have been tackled

In the work reviewed, relating to indoor soundscape, the keywords in the ISO soundscape definition, have been paid attention to, including acoustic environment, perception, person, and context.

A range of sound sources has been considered, including traffic sounds, human sounds, natural sounds, and various indoor sound sources. Different places have been studied, including residential settings and care homes, and different spaces in those places. Various users have been considered, including people working from home (WFH) and elderly people.

A framework for indoor soundscape is needed

The Systematic Review shows that many studies used the term 'soundscapes' but only a few studies reported using the ISO 12913 standard soundscape approaches and methods. On the other hand, it has been found that a range of wellbeing measures and perceptions were examined as outcomes including annoyance, stress, anxiety, loneliness, pleasantness, eventfulness, satisfaction, anxiety, and quality of life, although few studies assessed physiological outcomes such as heart rate.

Indeed, people perceive indoor spaces differently compared to outdoor spaces, and therefore, the indications and frameworks developed based on outdoor spaces need to be re-examined. For example, Torresin et al [10] developed an indoor soundscape model for residential buildings, as shown in Figure 1. By applying principal component analysis, Comfort, Content, and Familiarity, were extracted as the main perceptual dimensions explaining respectively 58%, 25% and 7% of the total variance in the participants' response to a balanced set of indoor sound environments exposures. Also, Comfort, Content, and Familiarity were found to be better predicted respectively by loudness N_{10}, level variability L_{A10}-L_{A90} and sharpness S. For other indoor spaces, such as care homes, etc. such frameworks could be different.

[10] Torresin S., Albatici, R., Aletta, F., Babich, F., Oberman, T., Siboni, S. and Kang, J. Indoor soundscape assessment: a principal components model of acoustic perception in residential building. Building and Environment, **182**, 107152, 2020.

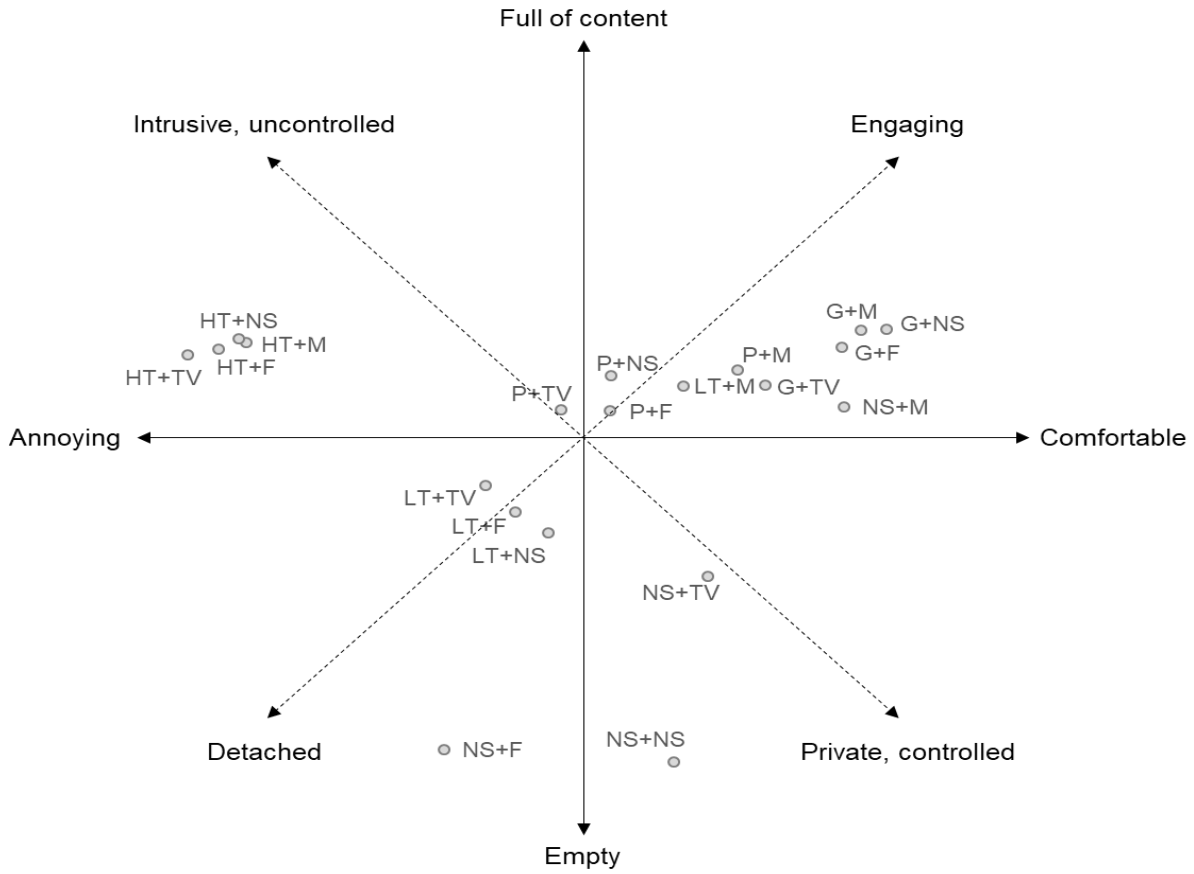

Fig. 1. An indoor soundscape model for residential buildings (Torresin et al 10), where similar to the pleasant-eventful model developed for outdoor soundscapes, an indoor soundscape that is both comfortable and empty, is private/controlled, and an indoor soundscape that is both annoying and empty, is detached.

It is noted that compared with outdoor spaces, for indoor spaces, more aspects need to be considered in terms of the effects on health and wellbeing, as people's duration of stay is much longer, and they are used for more types of activities, including work, sleep, audible safety, etc., in addition to restoration and comfort, which is the focus of outdoor soundscape studies. Therefore, careful considerations are needed for the framework of indoor soundscaping, considering different kinds of usages, although in the meantime, it is also useful to make better use of the existing standardised methods and response scales,

More rigorous work is needed

It was found in the Systematic Review that the quality of the statistical analysis and qualitative analyses was often poor, and few studies reported multivariate statistical analyses.

Although some useful results are given, such as 'the ideal WFH soundscape was a quiet, well-sound insulated environment, with access to positive sounds (i.e., natural sounds, music, urban background), ensuring privacy, intimacy, and self-expression', 'noise experienced in the home from neighbours during Covid decreased comfort and relaxation', and 'sound was important for social relationships, engagement and reducing loneliness in care homes for dementia patients', the relevant evidence for those findings was mostly rated as having 'low' or 'very low' confidence, due to the sample size, sample selection method, and quality of the statistical analysis, as mentioned above.

There is also a lack of longitudinal studies, which is rather important for indoor soundscaping, compared with outdoor spaces. There is also a lack of intervention studies (such as the role of better sound insulation), which is in fact a common current limitation of both indoor and outdoor soundscape studies.

One could argue that part of the reason for the poor-quality ratings, as reviewed in Volume 1, is a potential conflict of research approach in the field of soundscape research and health care research. The GRADE method used to evaluate the studies in the Systematic Review (Volume 1) was developed to evaluate health care research. For example, randomised controlled trials (RCT) (as might be used to evaluate a new medicine) are graded high quality designs, but observational studies (like those reviewed) are graded low. There are good reasons for this, but researchers from outside medicine or epidemiology sometimes argue that RCTs and other medical research designs are not always appropriate (or possible) for some research topics in soundscapes, as also acknowledged in Volume 1 that the sampling evaluations "could reflect an inherent tension between the methodologies typically employed with 'soundscape' research to date in terms of selecting a sample versus the rigorous quantitative approach to population sampling expected by GRADE". It would be useful to, using a very large, stratified sample subjected to a RCT with an active intervention as a bench mark, and then discuss and determine what the optimal design might be for indoor soundscape research.

More work on UK context is needed

While the Systematic Review shows that the current studies were conducted across a range of continents and countries including Asia (Afghanistan, China, India, Japan, Singapore, South Korea), Europe (Bulgaria, Italy, the Netherlands, Slovakia, Sweden, Spain), Australia, and Canada, studies from the United Kingdom are relatively limited. Since a key feature of soundscape studies is its context-dependence, as mentioned in the ISO soundscape standard, it is suggested that more work in the UK context is needed. More specifically, studies would be needed considering the special characters of residential buildings in the UK, both architecturally and socially; considering the influence of climate conditions in the UK including effects of climate changes; considering special needs of different types of users in the UK, and considering the effects of relevant regulations and policies in the UK.

Limitation and scope of this review

In the current Systematic Review, relevant conference papers were not included in the search. While this is reasonable as conferences in the field of soundscape are normally not peer-reviewed, it is noted that many researchers and practitioners in this field only publish conference papers. It would be surprising if conference papers contain more rigorous studies then those evaluated from the peer-reviewed literature, but novel concepts, hypotheses and pilot projects are often seen there. If time and resources allow, it would be useful to search for relevant conference papers, at least for the purpose of finding issues which have been mentioned and examined.

This Systematic Review focuses on studies published in the past four years. Although soundscape is a fast-developing field, many previous papers still have a long shelf life, and their results are still applicable today. Therefore, if time and resources allow, longer periods could be covered.

2. SUMMARY: RECOMMENDATION FROM AN INDOOR SOUNDSCAPING PERSPECTIVE

While the key issues in indoor soundscaping have been covered, more in-depth and rigorous studies are needed, considering:

- Establishment of indoor soundscaping frameworks,
- More rigorous study design and analysis,
- More longitudinal studies,
- More intervention studies,
- More attention to the UK context.

3. ABOUT THE AUTHOR

Professor Jian Kang holds Chair in Acoustics at the Bartlett Faculty of Built Environment, University College London, UK.

He is Fellow of Royal Academy of Engineering, and Fellow of UK Institute of Acoustics. He is President of the International Institute of Acoustics and Vibration, and he also chairs the European Acoustics Association Technical Committee for Noise, and EU COST Action on Soundscape of European Cities and Landscapes.

He has worked in environmental and architectural acoustics for 30+ years, with 80+ research projects, 800+ publications, and 90+ engineering/consultancy projects.

He is recipient of the Advanced ERC Grant Award, currently working internationally on developing Soundscape Indices.