

Supplementary Material—Coding

Codes	Excerpt
Q1. ACOUSTIC DESIGN AND REGENERATIVE BUILDINGS	
Theme: Dealing with complexity in user-building and building-city interaction	
Importance of acoustics	<p><i>"I think that <u>good acoustics is foundational</u>. I actually believe that is the most important element."</i></p> <p><i>"In many aspects <u>people have a choice on what they choose to see or not to see</u> in any particular environment, they may be able to change their view. There is more discretion, personal agency and control on it".</i></p>
Acoustics underestimation	<p><i>"<u>Design at the moment is so visually driven</u>"</i></p> <p><i>"I think there is the assumption within the design community and even in some cases in the traditional acoustics community that if we just improve the acoustics a bit but make sure that the visual is really, really good then we have accomplished something important. And my response to that is that you have made a step in the right direction, but <u>we are still underselling the importance of acoustics</u> if that's considered an accomplishment [...] It is better than nothing, but this is far from the whole picture"</i></p> <p><i>"[auralization] It is not a panacea, but a step forward than what we have today where <u>people just see visual models of things.</u>"</i></p>
Need for scientific evidence	<p><i>"<u>we haven't even begun to research the importance of acoustics to people in the built environment</u>".</i></p> <p><i>"We are living in a kind of transition phase and this is where <u>we need a lot more evidence</u> across soundscape"</i></p> <p><i>"But I think <u>with the right evidence</u> policy makers would be much more willing to demand developers to change something. What they do want is happy people who are not complaining about buildings..."</i></p>
Perceptual approach	<p><i>"the reason why we find it hard to find evidence from an acoustic perspective at the moment is because most acoustic research doesn't support that, because <u>it's not measuring the human perceptual response.</u>"</i></p> <p><i>"<u>thinking about people's perception</u> rather than just sound insulation, reverberation time..."</i></p> <p><i>"[the acoustic community] is attempting to measure the perceptual response through A-weighted dB units; without being too critical. [...] the A-weighted dB unit <u>is not anywhere near accurate enough to capture the human perceptual response.</u>"</i></p>
Rethinking technologies and design solutions	<p><i>"I think there is a range of technologies [...], not just to consider sound as noise, or waste, but also as a resource... Something we can think about is <u>not only reducing the negative effects of noise but also promoting the positive effects of sound.</u>"</i></p>

	<p><i>"I think there are two ways to get better acoustic design into green buildings and dwellings... Much work has already been done, for example, by putting sound insulation, reverberation time requirements and noise level requirements in building and design practices. This is very positive but it's a more traditional approach. [...] But beyond that...we can go further by <u>introducing positive ways of using sounds, such as using sound masking systems inside of open plan offices and also creating some restorative spaces, for example in large shopping malls.</u>"</i></p> <p><i>"Soundscape is also a framework because there are many potential routes to meet the minimum specification. That is <u>good news for designers and practitioners because it provides a lot of flexibility.</u>"</i></p> <p><i>"From the sound path viewpoint, differently from traditional technologies based on reducing noise, we also think about how to <u>manipulate or adjust different kinds of sounds, so the treatment may be good for certain frequencies but not for other frequencies.</u> [...] From the receiver viewpoint...which is the most important perspective in soundscape practice ... we need to think of different people and different contexts, ...so overall...<u>the design philosophy or technology would be quite different from</u> [that used in] <u>traditional noise control methods.</u>"</i></p>
Multisensory research	<p><i>"There is a need to cover a much more accurate picture of the foundational importance of acoustics to the <u>interaction of the acoustic sense with all of the other senses.</u>"</i></p> <p><i>"<u>Multisensory design is becoming a better understood concept</u> and a concept that has been much more widely promoted and quite widely seen".</i></p>
Multidisciplinary approach	<p><i>"we need to <u>talk also with psychologists, medical people...</u>"</i></p> <p><i>"It's a <u>multidisciplinary scientific approach</u>"</i></p>
Participatory process	<p><i>"This is the core of the soundscape approach. We are interested in how people perceive and experience the acoustic environment in context... If you apply this definition to indoor soundscape design, you understand that it's mandatory to <u>involve people not only in the evaluation but also in the design of buildings</u>"</i></p> <p><i>"I think that these types of design measures should be <u>negotiated with people living in the places, in the buildings</u>"</i></p>
Integrated design	<p><i>"To me the best way to address good acoustic quality is to <u>implement integrated urban design and planning approaches</u>, thus taking into account not only the acoustical dimension of the places but also the spatial ones and other environmental characteristics of spaces."</i></p> <p><i>"If you really want to get great quality of indoor places you need to <u>take into account that your buildings are placed in neighbourhood</u>, you have to take into account what kind of mobility is going on in the neighbourhood."</i></p> <p><i>"<u>Integrated assessment of acoustics and overheating and ventilation...</u>Traditionally in the UK they have been considered separately, so you do the noise assessment assuming the window is closed and if you do an overheating assessment you assume the window is open."</i></p>

Q2. DIFFERENCES AND SIMILARITIES BETWEEN OUTDOOR AND INDOOR SOUNDSCAPE APPROACHES

Theme: Differences in context - expectations

Context - expectations

"I think that [soundscape] methods are equally valid for any environment whether it's indoor or outdoor because we don't turn off our acoustic sense. The response, according to the soundscape model theory, is modulated by the context and our expectations. Our expectations outdoor might be different from our expectations indoor but we are still having a response to the acoustic environment."

"In outdoor spaces people may not stay as long and there may be much more choices where to stay. In a hotel atrium or in a museum for example, you often don't have many spaces to choose. Also, in indoor spaces people may have longer exposure to sound, such as in open plan offices [...] There are many differences and also people's tasks are different."

Theme: Differences in the acoustic environment

Acoustic environment

"Indoor spaces have reverberation associated, so the sound disturbance between sources can be stronger than outdoors."

"So, it can be useful to have some external desired sound from outside to mask unwanted sound from your neighbours otherwise you may need higher indoor sound insulation."

Theme: Differences in soundscape strategies

Soundscape strategies

"The risk of having high insulation to the outside is that you might hear your neighbours more; and the sounds of your neighbours can sometimes be much more annoying than the sounds from outside. So, it can be useful to have some external desired sound from outside to mask unwanted sound from your neighbours otherwise you may need higher indoor sound insulation."

"Lots of what has been learnt about the outdoor sound environment, lots of the approaches could be used [indoor]. In outdoor environments we mostly focus on natural sounds over non-natural sounds. Inside, there is a lot of talk and attention on bringing outdoor sounds inside."

"In indoor spaces is more challenging to get sonic stimuli from nature, because we know that we usually get sonic stimuli from nature outside."

"Music is a popular masking sound. Ideally, people like to hear their own music rather than other sources of sound. Maybe it's more important to provide the opportunity for people to shape their own sound environment with the sound they prefer."

"I have started to use headphones and I am surprised by the extent to which I feel unconnected to the rest of the office when I do that. It increases my personal space, to not be disturbed and interrupted. [...] But is it [wearing headphones] a failure of the acoustic environment or is it a good way to manage it?"

"Nothing replaces having good acoustics. Having good acoustics in the design of a building is the foundational element. [...] Like a concert hall that is designed to be able to play a range of types of music, if you have really good acoustics principles in the design of the building then you can put many kinds of music in there, it is fit for purpose for a multitude of uses".

"I would avoid superimposing supposed positive sounds into an environment because something that is good for you, might be not good for me. [...] There might be the possibility to add some wanted sounds, but still I think that these kinds of design measures should be negotiated with people living in the places, in the buildings."

Q3. HOW TO "MEASURE" INDOOR SOUNDSCAPES

Theme: Methods for the subjective response

Application of soundscape
measurement methods
indoor

"I think that [soundscape] methods are equally valid for any environment whether it's indoor or outdoor because we don't turn off our acoustic sense. The response, according to the soundscape model theory, is modulated by the context and our expectations. Our expectations outdoor might be different from our expectations indoor but we are still having a response to the acoustic environment."

"When you apply these kind of methods indoor there should be a [...] specific translation of those methods. For example, soundwalks may not be appropriate in indoor spaces. For example, you don't normally walk [i.e. while performing the main task] in open plan offices or in restaurants [...] So maybe using the same principle you can design new survey methods, but the principle is the same, just finding out what is people's perception when they are using the space. So, once you keep that in mind, I think even consultants could design something along with the ISO standard way."

Soundscape prediction

"It would be difficult for buildings that don't exist because soundscape only exists in the minds of people in the context. So, it is very difficult to do simulations to ask and understand 'how do you feel in this building?'. Usually, in current practice, you can only get into an existing building [e.g. post-occupancy] and ask how they feel."

Questionnaires, interviews

"A better application of questionnaires and surveys methods [is needed] to gain information from people about their environment... the soundscape theory has information about the type of survey methods that can be used."

"When I answer the questionnaires about my sound environment, I always feel that the questions are not quite the way in which I think about it or I would describe it. Interviews would be the best way to collect soundscape data."

Non-participatory
observations

"If you are listening actively or passively to the environment, this changes the perception of the environment. As soon as you ask somebody about how they feel about the sound, they start listening actively, in a different way than before you asked them."

"With non-participatory methods you can better understand what people are going to be like in their environment."

	<p><i>“Non-participatory methods to assess the human response in context because they are <u>very accurate</u>”</i></p> <p><i>“Any biophilic element needs to have the right sort of acoustic profile that is going to support the work or the usage of the space. And again, this can be done by measuring and assessing, using psychoacoustic principles and, where possible, <u>non-participatory observation...</u>”.</i></p>
Soundwalks	<p><i>“Usually when I lead soundwalks I have discussions with the participants. So, you not only <u>collect feedback from the single participant</u>, but you can also <u>get feedback or patterns emerging from the group discussion</u>, from the exchange that participants have among them after the soundwalk.”</i></p> <p><i>“If you lead soundwalks with people you somehow <u>invite them to reconnect with their sensorial experience of the places</u>, you invite them to retune to their environment and this is something we are not so used to [because] we always wear headphones, we tend to stay detached somehow from the environment.”</i></p> <p><i>“I think that <u>soundwalks</u> could be also <u>led indoors</u>.”</i></p> <p><i>“When you apply these kind of methods indoor there should be a [...] specific translation of those methods. For example, <u>soundwalks may not be appropriate in indoor spaces</u>. For example, you don’t normally walk [i.e. while performing the main task] in open plan offices or in restaurants [...] So maybe using the same principle you can design new survey methods, but the principle is the same, just finding out what is people’s perception when they are using the space. So, once you keep that in mind, I think even consultants could design something along with the ISO standard way.”</i></p> <p><i>“What is not obvious when you do [a soundwalk] is how you might feel if you were there for a longer period of time, <u>how much habituation you need in one place in order to get the sense as if you were there for a longer period of time</u>.”</i></p>
Mobile apps	<p><i>“Through the <u>use of mobile apps people can collect data; can give their feedbacks on the quality of the indoor places independently from the researchers</u>. People can work autonomously, they are not influenced by the researchers and mostly <u>they can collect the data when they feel they need to share and they want to provide feedback</u>.”</i></p>
Auralization	<p><i>“Auralization and visualization techniques can be used to support decision making and planning and <u>help people to better assess the human perceptual response in context before things are completed</u>. However, the auralization demo <u>could be very different than</u> [what users may experience] <u>when having to live in the environment 24/7</u>. It is not a panacea, but a <u>step forward</u> from what we have today where people just see visual models of things.”</i></p>
Triangulation	<p><i>“My preference, my preferred method, is to use a <u>combinational method</u> because I think if you use a combination you can cross validate your findings and also more robustly support findings that you have.”</i></p>

Theme: Methods for the acoustic environment

Psychoacoustic data

"Collecting psychoacoustic data helps to really broaden out the picture of the acoustic assessment of the environment and helps to explain the human perceptual response in context. So, better use of psychoacoustic data integrated with traditional methods is one very important thing."

"[the acoustic community] is attempting to measure the perceptual response through A-weighted dB units; without being too critical. [...] the A-weighted dB unit is not anywhere near accurate enough to capture the human perceptual response."

"Better instrumentation [is needed] to measure and to collect better acoustic data based on psychoacoustics."

"Any biophilic element needs to have the right sort of acoustic profile that is going to support the work or the usage of the space. And again, this can be done by measuring and assessing, using psychoacoustic principles and, where possible, non-participatory observation..."

New indices

"We are at the beginning of investigating how to synthesize or harmonize different forms of measurements to fully assess the human perceptual response."

Q4. POTENTIAL OF SOUND MANAGEMENT FOR BIOPHILIC DESIGN

Theme: Reproduction of natural sounds indoor

Natural sounds indoor

"Lots of what has been learnt about the outdoor sound environment, lots of the approaches could be used [indoor]. In outdoor environments we mostly focus on natural sounds over non-natural sounds. Inside, there is a lot of talk and attention on bringing outdoor sounds inside."

"In indoor spaces is more challenging to get sonic stimuli from nature. because we know that we usually get sonic stimuli from nature outside."

"You could somehow enhance the sonic stimuli coming from nature indoors if you work with different materials for pavements. You can use wood or gravel."

"Sometimes, if we cannot connect to nature outside 100% visually, but we use sound, we can enhance it. Then the overall effect can be greater. And, vice versa. If you want people to appreciate outdoor sounds like water... if people can't see it, then it can sound like white noise and people may be not happy [...] A window would be good, otherwise you can have pictures of natural scenes."

"If you want to recreate what happens in nature indoor you have to recreate the fluctuation in sound, spectral content, sound level, type of sound...."

"Any biophilic element needs to have the right sort of acoustic profile that is going to support the work or the usage of the space. And again, this can be done by measuring and assessing, using psychoacoustic principles and, where possible, non-participatory observation..."

Audio-visual interaction

"You can use sound to enhance people's appreciation of low-resolution pictures. So, for example, if you see a very beautiful fountain you are really like it, but if you see it at a low resolution but there is some sound, this can enhance it. Sound can be used to enhance the picture quality."

	<p><i><u>"Sometimes, if we cannot connect to nature outside 100% visually, but we use sound, we can enhance it. Then the overall effect can be greater. And, vice versa. If you want people to appreciate outdoor sounds like water... if people can't see it, then it can sound like white noise and people may be not happy [...] A window would be good, otherwise you can have pictures of natural scenes."</u></i></p> <p><i><u>"In enclosed spaces, a kind of restroom, they played bird sounds. On a wall there was a very big picture of a forest with birds. People felt much better. Although it was not real, it was fake, but there were some kinds of interaction. If you only play sounds of birds without a visual correspondence, people would feel it very differently."</u></i></p>
Limitations	<p><i><u>"Personally, I don't like being played fake birdsong rather than real birds. I find recorded birdsong a bit fake."</u></i></p> <p><i><u>"I am sceptical that you can get some good sonic stimuli from nature indoors unless you use augmented technology to do that. But I am not so much a fan of artificial soundscapes."</u></i></p> <p><i><u>"One of the potential challenges of biophilic design is that, what happens if you have different tenants? What happens if you go to rent the building to someone else and maybe they don't want waterfalls, they want something totally different?"</u></i></p> <p><i><u>"The biophilic elements are more like interior design features, they can be used if that suits the environment and people who are working there. But also, if they are taken out, people can still have a good quality acoustic environment..."</u></i></p> <p><i><u>"Nothing replaces having good acoustics. Having good acoustics in the design of a building is the foundational element. [...] Like a concert hall that is designed to be able to play a range of types of music, if you have really good acoustics principles in the design of the building then you can put many kinds of music in there, it is fit for purpose for a multitude of uses"</u></i></p> <p><i><u>"Biophilic design is a tool, it is not the solution."</u></i></p> <p><i><u>"I would avoid superimposing supposed positive sounds into an environment because something that is good for you, might be not good for me. [...] There might be the possibility to add some wanted sounds, but still I think that these kinds of design measures should be negotiated with people living in the places, in the buildings."</u></i></p>

Q5. "WANTED" SOUNDS AND HEALTH OUTCOMES

Theme: Need to review current noise limits and metrics from a soundscape perspective	
WHO guidelines	<p><i><u>"The limiting factor in every case for the environmental noise limits [in WHO Environmental Noise Guidelines for the European Region guidelines] was annoyance. So, the [WHO] guideline levels, which are external noise levels, are based on annoyance rather than other health impacts of noise."</u></i></p> <p><i><u>"People may want a calm environment, but they don't want a monotonous or boring environment, they might want an exciting environment, they don't want a chaotic environment. Acoustic boredom, being in a monotonous acoustic environment is just as frustrating as being in a chaotic environment because they are both unwanted. It is not a function of the decibel level, it's a function of the perceptual response in context."</u></i></p>

"Because the way in which noise is measured and assessed [in WHO guidelines], it has not incorporated soundscape techniques [...] Because they are only considering dose-response evidence based on decibel levels, it is already incomplete evidence because we know that there is a greater ability to get more accurate evidence using augmented methods [i.e. from nonacoustical factors and psychoacoustic metrics] other than the dB units alone."

"It's controversial because they reviewed a lot of evidence but it doesn't matter. If you have got an imperfect measurement system, it doesn't matter how much evidence you have, you will still going to have imperfect outcomes. I challenge that findings, but there is going to be the need for a lot more evidence whether or not they are correct"

Threshold

"There is a kind of threshold, but this threshold may be different from space to space. For example, in outdoor spaces we found 65-70 dB LAeq in urban public spaces. But if you are sleeping, this threshold would be much lower. So, it really depends on what the task is and on what you do, and how long you have been exposed to sound. For example, if you are exposed to a fountain for 5 minutes, that's fine, but if there is one fountain next to your desk, even if it is 30 dB, you may still feel annoyed after certain time."

"I think the principle is, below a certain level the type of sound is more important, if it's positive or negative. But above a certain level you need to be careful. Although sometimes with positive sounds people are happy, but it is not good for their health. For example, in a very loud disco people are happy, they are not annoyed, but that is not necessarily good for their ears and heart."

"None would like to live in an anechoic chamber, we might want calmness at certain time but it doesn't mean absolute silence"

Availability of control

"The key thing is about occupant control of the environment because when the occupants have control over their environment, they feel differently about it so they may rate it differently. [...] That concept of having control over the environment changing your response to certain environmental conditions is embedded in the adaptive thermal comfort model."

"From a pure soundscape perspective we would say, if I am choosing, I have control over my environment, I know if I am going to open this window I am going to hear some unwanted sounds but I may prefer that than this monotonous environment that is driving me crazy...Seen radically from a soundscape perspective we would say that because I have control over that situation, I am choosing it, therefore I am moderating my own cognitive response to this and [...], you may then not have the stress response that you have when you feel angry about the noise and no control to stop it."

"It is not ideal. Ideal would be that people would not have to make a choice between thermal and acoustic comfort and noise pollution."
