inter•noise 2009
innovations in practical noise control
2009 August 23-26
Ottawa, Canada

The positive soundscape project: A synthesis of results from many disciplines

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ABSTRACT

This paper takes an overall view of ongoing findings from the Positive Soundscape Project, a large inter-disciplinary soundscapes study which is nearing completion. Qualitative fieldwork (soundwalks and focus groups) and lab-based listening tests have revealed that two key dimensions of the emotional response are calmness and vibrancy. In the lab these factors explain nearly 80% of the variance in listener response. Physiological validation is being sought using fMRI measurements, and these have so far shown significant differences in the response of the brain to affective and neutral soundscapes. A conceptual framework which links the key soundscape components and which could be used for future design is outlined. Metrics are suggested for some perceptual scales and possibilities for soundscape synthesis for design and user engagement are discussed, as are the applications of the results to future research and environmental noise policy.

1. INTRODUCTION

The concept of the soundscape is a broad one, accommodating the complete sound environment in a location and the human response to it. It thus attracts interest from many academic disciplines. One key quality of the soundscape concept is that it seems to be a better fit than noise level to the many factors influencing human experience in the outdoor environment. Different disciplines have tended to focus on subsets of these factors and, though there is a wide agreement that a holistic perspective is desirable, most soundscape projects are grounded in a single discipline. The Positive Soundscape Project (PSP) set out from the start to be interdisciplinary – that is, to synthesise a shared perspective on soundscapes from a range of disciplines. The disciplines involved in PSP are acoustics, manufacturing, sound art, social science, psychoacoustics, physiology, and neuroscience. The project objectives that are relevant to the work discussed in this paper are:

- To determine what individuals/groups perceive to be component parts of a soundscape.
- To determine how individuals value these components.
- To classify types of soundscape.
- To bring together artistic, social, psychological and physical science and manufacturing approaches.

Similar questions have been explored before; though mainly from within discipline boundaries. A range of approaches have been used to establish classifications and categorisations of sounds and soundscapes. For example, Maffiolo et al[1] asked listeners to sort urban soundscapes (based on loudness or pleasantness) and found two generic categorisation types; ‘event sequences’, where individual sounds can be distinguished within the soundscape and ‘amorphous sequences’, whereby sounds are not easily distinguishable. Other research, for example Kuwano et al[2], has shown that a soundscape is often perceived as a collection of the individual sounds of which it is comprised; soundscape assessment is therefore influenced by the assessment of those sound types. This implies that soundscape assessment relies upon the identification of the sounds, the prominence of the sounds, and potentially the ratio of certain sound types to other sound types within the soundscape.

When characterizing listener impression of the soundscape, several researchers have attempted to decompose the perception into its principal components. (The term perception is used quite loosely here because the principal components usually include rather high-level cognitive-emotional concepts.) For example, Kang[3] used semantic differential scales to rate impressions of the soundscapes of urban squares. The bulk of the variance was explained by four dimensions, named Relaxation, Dynamics, Communication and Spatiality. This and similar studies raise many interesting questions on how to connect these dimensions with qualitative categorisation work on the one hand, and how to translate quite broad dimension names into quantitative measurements and hence to the acoustic sound field, on the other hand. Even if this can be done, there still remains a significant gap in connecting scientific studies of the soundscape to the adventurous explorations of sound artists.

PSP seeks to build a shared perspective on soundscapes from many different disciplines. This paper outlines some key results and explores where the different disciplines agree (and where they do not yet!). In several cases, specific experiments within PSP are explored in more detail in papers elsewhere in these proceedings.

2. CONCEPTUAL FRAMEWORK

Early on in the project, the research team realized that our discussions would be helped if we proposed a conceptual framework to draw the different research strands into a single place. Figure 1 illustrates the resulting 'sound-scape' model proposed by Cain et al[4]. It places individual sources within a spatial area, each source having potentially several properties (some quantifiable like loudness and roughness). These interact within the 'scape' to produce an overall listener impression. The listener impression also depends on several other factors such as their expectation, the time of day (and year). The listening state modeled by others (e.g. Truax[5]) is mapped to the factor 'activity': how a listener experiences the soundscape will depend on what they are doing. Activity is easier to assess and model than listening state, and is one of the features that potentially allow this model to be used for design. Having generated a conceptual framework, experiments are necessary to see to what extent it models perception of a soundscape.

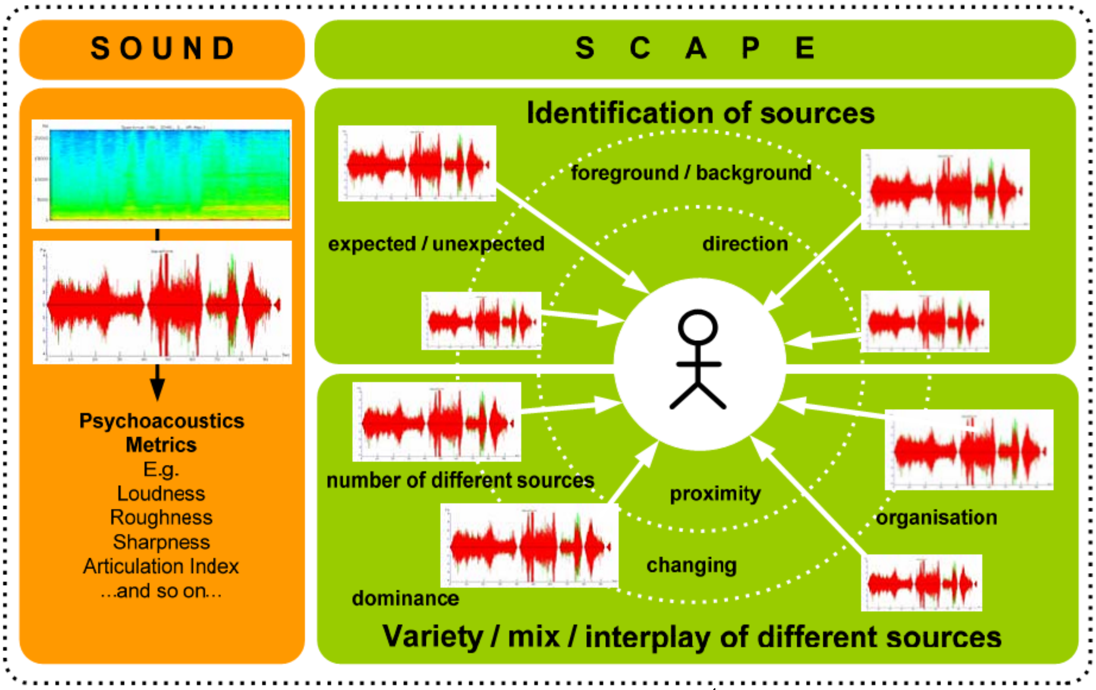


Figure 1: The Sound-Scape conceptual framework, after Cain et al.[4]

3. MULTIPLE METHODS

Following an initial pilot test[6] the project decided to use multiple methods to intensively study a small number of places. The main methods used were chosen because they each seemed capable of capturing key elements of listener experience. The methods used were: sound walks, interviews, focus groups (all qualitative), laboratory listening tests (qualitative and quantitative), physiological measurements, including functional magnetic resonance imaging (fMRI, quantitative), synthesis and reproduction (artistic and quantitative) and questionnaires (artistic). Early on, the team chose to focus on external urban soundscapes, partly because these represented potential for variety, conflict and the need for design. The field work all centred on two sound walk routes, one in Manchester and one in London. Each route linked a series of key soundscapes.[7] The Manchester route traveled from a pedestrianised shopping street (Market Street), through an indoor shopping mall (Arndale Centre), to a pedestrianised square (St Ann's Square), along a main road with high traffic levels and shops, to a small park shielded from traffic (St John's Gardens). In each key space, a short interview took place based on the following questions:

- What can you hear at the moment?
- What do you like most? Like least? Why?
- Does anything dominate?
- What do you think is in the background?
- Does this location sound as you would expect it to?
- How does this location make you feel?
- What aspects of the surroundings of this location do you think have an impact on the soundscape?
- Which of these aspects make the soundscape better/worse?
- How do you value this space?
- Who would you think uses this space?

Binaural recordings were made of the soundscapes along the soundwalk route for laboratory listening tests. The results reported here are from two listening tests. In the first listening test, listeners evaluated a new set of eight 30s recordings on six semantic differentials and a principal component analysis (PCA) was conducted to characterise the dimensions of listening space. The stimuli for this test were reproduced at the original recorded level. The question asked of the listeners in this test was "How does the soundscape make you feel?" and the rating scales used were: calmness & relaxation, comfort and reassurance, vibrancy & arousal, informative, intrusiveness, pleasantness. Cain et al[8] describe this experiment in more detail.

As preparation for some of the physiological work, the opportunity was taken to conduct a second listening test. This was essentially an independent repeat of the first listening test. It used more (150) but shorter (8 s) soundscape stimuli, built from the project recording database. They were generated to produce a large range of subjective pleasantness ratings. This time, the stimuli were equalized for L_{Aeq}. The same semantic scales as in test 1 were used for rating.

Once semantic ratings had been captured for the 8s soundscape stimuli, the recordings were played to subjects in an fMRI scanner.[9] fMRI scanners offer near real-time measures of blood flow within the brain, information which can be interpreted to show which areas of the brain are most active when the subject listens to each soundscape. This part of the project sought to obtain neurological validation of the PCA dimensions developed from the listening tests. In a separate experiment, heart rate and respiratory rate of subjects listening to the same 8s stimuli were measured.[10]

Alongside these methods built around the soundwalk recordings, we also conducted four focus groups. A focus group is simply a discussion on a specific issue facilitated by a researcher. Naturalistic discussion allows ideas to emerge and be tested by the group, so that the researcher can potentially capture detailed and relatively unbiased opinions. The aims of these focus groups were to explore the idea of a positive soundscape and how a soundscape affects behaviour and psychological response. The four focus groups used different participants:

- Adults aged 18–25 years of age,
- Adults aged 60 year of age or older,
- Hard of hearing adults with moderate to severe hearing loss who use assistive listening devices (e.g. hearing aids or cochlear implants) and
- Experts (professionals from urban design and development or acoustics).

Finally, an artistic understanding of the soundscapes studied was developed through methods such as:

- The favourite sounds survey,
- The development of a soundscape sequencer,
- The commissioning of projected versions of the urban soundscapes 20 years from now,
- The curation of the gallery exhibition ‘Sound Escapes’ that presents audio and visual works on the theme of positive approaches to soundscapes and includes contributions from all the disciplines involved in PSP.

The favourite sounds survey continues in Manchester and London the project begun in the capital in 1998.[11] It consists of asking people for their favourite sound of Manchester, or London, their favourite sounding place in those cities and, as importantly, why. As well as supplying data for the sequencer and listening tests the survey gives specific examples of sounds and aural spaces that individuals find positive. Answers to the question ‘why?’ give insights into what individuals find positive in the environmental sounds that they hear. Recordings of the favourite sounds will be released on CD and via a Google map based website. The soundscape sequencer was developed in several versions, one of which was used in experiments where people were asked to interactively design (mix) their ideal urban soundscape.[12]

4. OUTCOMES

A. The listener in the soundscape

The focus groups explored the idea of a positive soundscape and how a soundscape affects behaviour and psychological response. Textual analysis of transcripts of the focus group recordings revealed some key preferences across all groups. Participants stated that perceived control over their sound exposure is important, and there are several strategies to regain control. Expectation of a soundscape and its compatibility with one’s behavior are also important. When asked to explain the soundscape concept, people often described soundscapes in foreground/background terms. Participants discussing the idea of a positive soundscape said that sounds that blend together are positive. Qualities of positive soundscapes include natural sounds, vibrancy and those that engender positive emotions. These results seem broadly in agreement with the framework in Fig. 1

B. Components of a soundscape

The transcripts of the soundwalk interviews were analysed to reveal a map of the language people use when talking about sounds and soundscapes. It was found that the terms used could be grouped into three concepts: sources, sound descriptors and soundscape descriptors. The relations between these are conceptualized in Fig. 3. The focus on physical objects and events is striking: sounds are associated with events (which have meaning). There is some evidence of a difficulty, a lack, in using language to describe sound and especially soundscapes. This lack of language may relate to a lack of an aesthetic of sound and perhaps reflects the dominance of the visual in the design and conceptualization of the environment. The division of the source/sound/soundscape does however seem to relate to the foreground/background concept for analyzing a soundscape, an idea which is widely used elsewhere (e.g. auditory scene analysis) and which emerged spontaneously from our focus groups. The emergence of these terms seems to also fit reasonably well to the framework in Fig. 1.

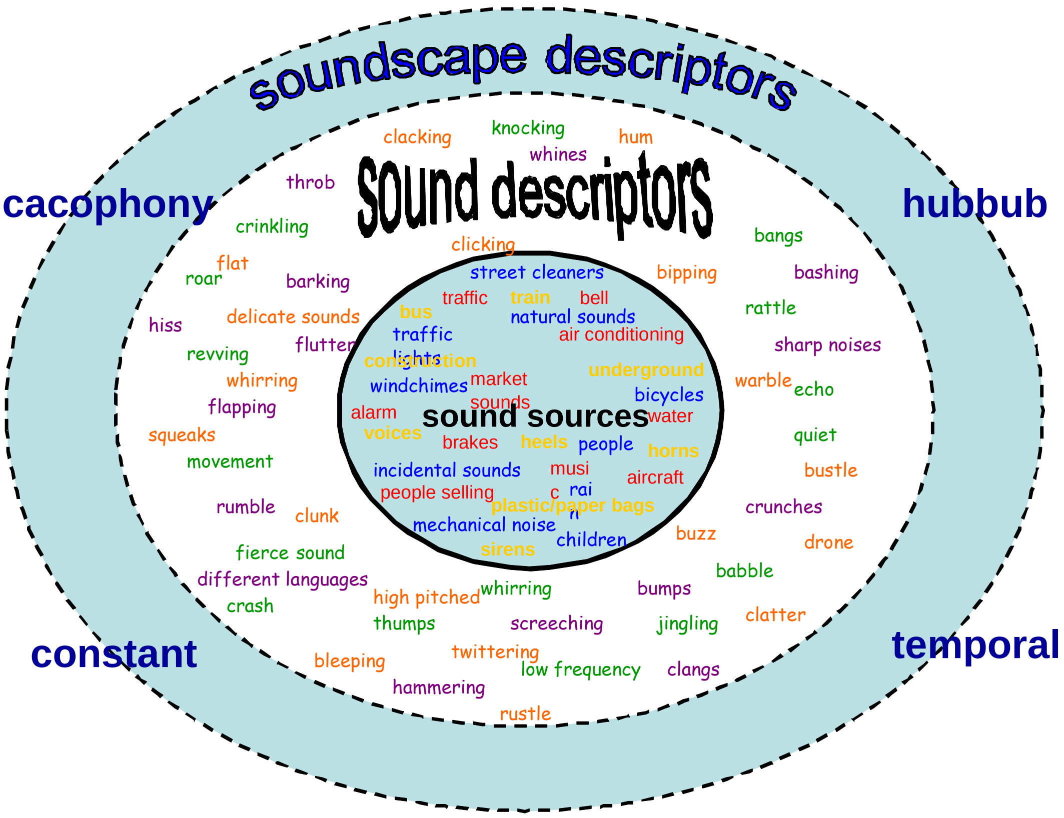


Figure 2: Main soundscape components revealed in qualitative analysis of soundwalk interviews.

C. Perceptual dimensions of a soundscape

The outer ring of the language map in Fig. 2 shows that soundwalk interviewees used four key concepts to think about the soundscape: Cacophony (a negative mix of sounds), Hubbub (a positive mix of sounds), Constant (an unchanging, sometimes monotonous soundscape) and Temporal (short term changes). It is tentatively proposed here that these can be arranged on two axes: Cacophony-Hubbub and Constant-Temporal. C-H describes the interaction of sources within the soundscape, and C-T describes change, evolution and dynamic range. The musicality of these axes is striking: C-H seems analogous to the way the instruments of an orchestra blend and C-T might relate to the changing score of the music. (Perhaps it is not surprising that these analogies can be made; if we struggle for ways to describe environmental sound, we may fall back on the established aesthetic language of music.)

The laboratory listening tests also found two dimensions[8], though they are not identical to the qualitative ones. Listening test 1, with 30 s recordings, found that almost 80% of the variance could be explained by just two principal components. Correlation coefficients to the semantic differential scales used by the subjects are shown in Table 1. Component 1 correlates with relaxation, comfort and intrusiveness. Component 2 correlates with vibrancy. These would seem to agree reasonably well with Kang's first two components, Relaxation and Dynamics. Following this result, Component 1 was tentatively named Calmness/Relaxation and component 2, Vibrancy. The relationship of the semantic scales to overall pleasantness is also shown in Table 1.

When this experiment was repeated in listening test 2, with different recordings, very similar results emerged, as shown in Table 2. (These results probably show less statistical noise because the stimuli were significantly shorter.) Because the recordings in test 2 were equalized for sound level, Table 2 provides clear evidence that noise level is not sufficient on its own to predict subjective response to a soundscape.

Table 1: 30s listening test: Component score coefficient matrix (varimax rotation).

	Component		
	1	2	Pleasantness
Calmness & Relaxation	.338	-0.87	.900
Comfort & Reassurance	.306	0.50	.858
Vibrancy & Arousal	-0.97	.950	.262
Information	.163	.217	.461
Intrusiveness	.336	-1.56	.812

Table 2: 8s listening test: Component scores

	Component	
	1	2
Pleasantness	0.825	0.144
Vibrancy	0.021	0.830
Calmness	0.895	-0.029
Comfort	0.848	0.138
Intrusiveness	0.791	-0.224
Informational content	0.031	0.788
Variance explained (%)	47.58	23.62

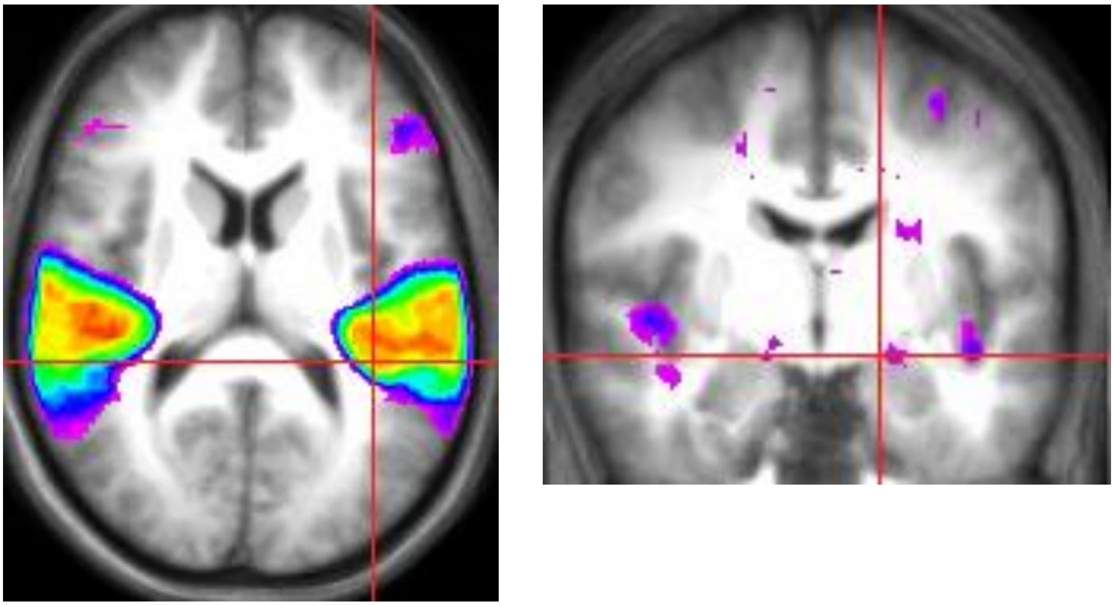
How do the qualitative axes relate to these principal components? First, it should be noted that they describe subtly different aspects of the listener experience. In the laboratory, subjects were asked how the soundscape made them feel. On the soundwalk, participants were describing the soundscape. These are the two essential features of the usual definition of the soundscape: the sound environment in a place (our qualitative axes) and the listener response to it (our quantitative principal components). Given that distinction, there does seem a strong relation. The qualitative axes, Cacophony-Hubbub and Constant-Temporal may describe the two ways in which a soundscape can produce an emotional response of Vibrancy in the listener. The first component, Calmness/Relaxation is more purely an emotional response and is strongly related to overall pleasantness. Thus it is suggested that the perception of the soundscape can be characterized by Calmness/Relaxation and Vibrancy, and

Vibrancy splits into two correlates, Cacophony-Hubbub and Constant-Temporal. This suggests a strong role for the sound artist in helping to compose the elements of the soundscape: the artistic task would be to design (compose) a suitable level of vibrancy by attempting to manipulate the mixture of sound sources and how they change over time. The parallel with musical composition is clear and we are reminded that many sound artists compose pieces of recorded 'soundscape' music as well as intervening in the soundscape of the built environment.

D. Physiological validation

Once the two principal components above had been established in listening tests, physiological validation was sought: if the cognitive response to a soundscape varies along these scales, then it is interesting to see what physically changes in the body and brain during this response. In the fMRI scanner, it was found[9] that passive listening to soundscapes engages several regions of the brain. Firstly, the difference between soundscape and silence shows activation in left and right auditory cortex, as shown in Fig. 3(a). Secondly, the difference between soundscapes rated neutral and high or low on factor 1 (calmness / pleasantness / valence) shows activity in the left and right amygdala in Fig. 3(b). This is a brain region associated with processing emotion. These results help to validate the perceptual finding that soundscape recordings equalized for L_{Aeq} produce significantly different cognitive responses depending on their content. Further analysis is now underway to seek neural correlates of the vibrancy scale.

Further evidence of physiological effects comes from the heart rate trials, which found that heart rate is slightly but significantly decreased by listening to a soundscape rated as unpleasant.[10]



(a) (b)

Figure 3: Average brain response seen in fMRI scanner to (a) difference between silence and soundscape, and (b) difference between soundscapes rated neutral and highly pleasant or unpleasant.

E. Measuring and designing soundscapes

Work is now underway to find objective metrics which correlate with the subjective components outlined above. The eventual best fit is likely to include measurements of individual prominent sources as well as the soundscape as a whole. Mean values over time will be tried for calmness/relaxation, while data expressing variation in source, spectrum and amplitudes over time will be examined for correlations with vibrancy. It is envisaged that validated quantitative metrics will eventually be used alongside qualitative methods for routine evaluation of real soundscapes.

Meanwhile, our early experiments with simulating soundscapes have indicated that it is possible to achieve a kind of ecological validity: participants make the same qualitative response to the simulator as they do to the real soundscape.[12] They also report feeling very engaged by the task of manipulating a simulated soundscape. Of course, current simulations are crude compared to, say, the state of the art in concert hall auralisation. Nevertheless, it seems reasonable to anticipate that we will eventually develop simulations realistic enough to be used reliably for built environment design.

5. CONCLUSIONS

The Positive Soundscape Project has synthesized the methods and results from several different disciplines to provide a coherent characterisation of listener response to an urban soundscape. People conceive of the three main soundscape components as sound sources, sound descriptors and soundscape descriptors. The distinction between sound and noise is essentially an emotional one. Results from listening tests and soundwalks have been integrated to show that the two principal dimensions of this emotional response seem to be calmness and vibrancy. Physiological experiments have so far demonstrated changes in the brain along the first of these scales. Further, vibrancy seems to have two aspects: organization of sounds (cacophony – hubbub) and changes over time. The long-standing artistic notion of the environmental soundscape as being a sort of musical composition has been borne out in these findings. The value of this interdisciplinary work is shown in the way that the findings of listening tests, qualitative fieldwork, artistic practice and physiological experiments largely agree, giving rigour.

There are many avenues for developing the work outlined here. The conceptual framework can now be refined in the light of experimental results to improve its utility in future research and design. Metrics will be proposed and will then have to be tested in a wider range of soundscapes and locations used in this project. The simple soundscape simulators could be developed towards several different targets: fully accurate systems for city design, online maps for public engagement and musical synthesis systems for artistic inspiration. It is hoped that this work will form part of the basis for the eventual routine assessment of soundscapes and their incorporation into environmental and planning policy.

ACKNOWLEDGMENTS

The Positive Soundscape Project is wholly funded by the UK Engineering and Physical Sciences Research Council, under grant number EP/E011624/1.

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