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ACOUSTIC DESIGN ARTIFACTS AND METHODS FOR URBAN SOUNDSCAPES

* Björn Hellström[1], Mats Nilsson[2], Peter Becker[3] and Peter Lundén[3]

University of Arts, Crafts and Design (Konstfack) and ÅF-Ingemansson AB, Stockholm, Sweden
[2] Gösta Ekman Laboratory, Stockholm University and Karolinska Institutet, Sweden
[3] The Interactive Institute, Stockholm, Sweden

bjorn.hellstrom@konstfack.se

Abstract

The research question is: "How to develop and apply acoustic artifacts and design methodologies for improving soundscapes in urban outdoor spaces?" In the project, this research question is limited to two specific types of urban outdoor spaces – city-park and city-square – and to two types of acoustic design artifacts. These are:

I. Dynamic promotion of qualitative site specific sounds (e.g., the overall site specific sonic atmosphere, sounds from human activities, birds and fountains), which creates an improved soundscape.
II. Sound-art installations, that creates delimited auditory sub-spaces within the park/square.

The purpose and method is:
1. To provide two case-studies of artistic soundscape improvement, one in a noise polluted city-park and one in a city-square. The case-studies will serve as models for future applications of the new acoustic design artifacts.
2. To create and validate an innovative acoustic design methodology based on state-of-the-art real-time acoustic simulation tools integrated into the design process. The methodology will be validated in psychoacoustic listening experiments and field studies.
3. To determine the potential of the two acoustic design artifacts (I Dynamic promotion of qualitative site specific sounds, and II Sound-art installations) for providing pleasant and restorative soundscapes, in order to strengthening the social interaction as well as the spatial and aesthetical qualities in noise polluted city parks/squares.

The present project beats a new track by combining *acoustic design* with *sound art research,* integrating methodologies based on *real-time acoustic simulation* and application of *psychoacoustic methodology* for validating simulations and for evaluating perceptual, emotional and behavioural effects on visitors to public open spaces. The ongoing research project, financed by the Swedish Research Council, is executed by the University College of Arts, Crafts and Design (Konstfack), Gösta Ekman Laboratory – Stockholm University and Karolinska Institutet and the Interactive Institute, all in Stockholm, Sweden.

INTRODUCTION

Generally, today our greatest acoustic efforts are concentrated on defensive strategies for protecting people in urban space. Without getting sidelined by these issues, it is time for offensive strategies that aim at exposing the urban space; to develop constructive and creative relations with the environment. Such strategies involve critical discussions on urban structure, strategic planning methods, spatial and temporal qualities, aesthetics and design. What is asked for are *qualitative aspects of urban space* in constructing and innovative perspectives, with regard to dynamic time-based design as well as to human interaction.

In brief, this project deals with design of creative solutions in order to improve the soundscape. It confronts the problem of noise pollution in outdoor areas from a design and art perspective, not from the conventional noise control perspective. The project also introduces and evaluates a methodology based on real-time simulation, as well as psychoacoustic evaluation models. Furthermore, the project challenges the visual dominance in urban planning, and is therefore highly relevant to urban research in general.

Regarding time schedule, the project runs for three years (2008-20010). We are now in the beginning of the planning process; therefore it is just possible to present basic principles and ideas regarding the project.

This paper is a result of an ongoing research project, executed by the University College of Arts, Crafts and Design (Konstfack), Gösta Ekman Laboratory – Stockholm University and Karolinska Institutet and the Interactive Institute, all in Stockholm, Sweden.

SURVEY OF THE FIELD

Soundscape Research and Sound Art

The Canadian composer and researcher R. Murray Schafer (1977) introduced the concept "soundscape". He defined it as "...the sound variations in space and time caused by the topography of the natural environment, the buildings and their different sound sources." The concept of soundscape implies an interdisciplinary approach to the acoustic environment. For a recent review of soundscape research in Schafer's spirit, see Truax (2001).

Significant for sound-art is the use of the public space as a fundament. Public space is generally considered being spaces and places intended for all citizens, in contrast to nature already cultivated. Examples of this are streets, squares, and open spaces in general. Characteristic for these places is that they are anti-hierarchic in a way that every person has access to them, regardless of economical or social background, see Fölmer (1999). The development of sound-art is to be seen as a reaction against the art music's distancing from a broader audience and its sealed concert halls. Instead the public sound-art is emphasizing the opposite: The public, and in many cases an interactive contact with the environmental surroundings. From a music-philosophic perspective, the genre is linked to John Cage's (1995) idea that sound and silence as material and indeterminacy as composition method, are to be regarded as equal with traditional materials and methods of composing, and in which all sounds are possible carrier of musical meaning.

Another component for the development of the public sound-art as genre, is the development of the installation art in the 1960's and the investigation of the space as concept, in which a questioning of the traditional art hall and gallery lead to the investigation of alternative

spaces outside the conventional ones, for instance the public space and nature, see Saxer (2006).

An increasing interest for sound as potential carrier of semantic meaning, research works in fields close to sound-art, like sound design, and also the development of technological accessibility has put focus also on sound-art in public space, see Minard (1999). Hellström and co-workers (Urban Sound Institute) has recently experimented with three permanent sound installations in a shopping mall in Stockholm City (Gallerian, Hamngatan). Lundén and Becker have produced a series of public soundscape installations (e.g. *Sonic Doors*, Swedish Pavilion at Expo2000 in Hannover).

Acoustic Design and Acoustic Simulation

The concept "acoustic design" has recently emerged from the architectural discipline (Hellström, 2002, 2003). Hitherto, architectural research has largely ignored the sound environment. Researchers advocating acoustic design add the dimension of sound as an important building block for architectural practice. Importantly, acoustic design integrates the soundscape with the place and its visual design, see Amphoux and Augoyard (1993, 1995). A place that "sounds good" is not necessarily quiet. A functional soundscape supports the activities of the place, its visual design, buildings and cultural and aesthetical connotations (see Hellström, www.acousticdesign.se, and CRESSON, the leading international institute for research on acoustic design, www.cresson.archi.fr).

A complete system for acoustic simulation and auralization (Kleiner et al 1993) in real-time has been developed in the EU-FP6-project Uni-Verse (http://uni-verse.org), by one of the partners in this project. In contrast to auralization systems available on the market, our system can perform the simulation in real-time. This will have a great impact on the usability of such tools for practicing architects. The system connects a software tool handling an architect 3D model, including material with defined acoustic qualities, with real-time acoustic simulation. Thus experiments in visual as well as acoustic effects of changes in form (geometry) and material are enabled. This will drive a shift towards architects integrating real-time acoustic experimentation by simulation into the design process. This means transforming the perspective on architecture itself, into a both visual and acoustic design. Investigating the potential of this approach has been made possible by innovative research results. In this project the *design methodologies* will be explored in a case study.

Noise Pollution in Urban Outdoor Spaces

Traffic noise pollution is a great and increasing environmental problem in urban areas (WHO, 2000). Conventional noise control techniques are only sufficient for providing good sound environments indoors with closed windows (today, facade reduction >40 dB is possible). The outdoor sound environment is more difficult to protect. Noise control methods typically fail, because of political, economical, safety, and aesthetic reasons. For example, ordinary noise barriers are often too expensive or visually intrusive in central urban areas. Noise reduction at the source, e.g., traffic-volume reduction or promotion of quieter cars and tires, are difficult or impossible for political reasons (Kihlman, 2006). Therefore, outdoor guideline values for traffic noise are typically exceeded in noise polluted urban areas.

Outdoor environments, particularly parks and green areas, provide invaluable opportunities for physical exercise and psychological restoration. Walks in urban parks acts as preventive measures for illnesses caused by a sedentary life style and stress. The risk is that noise pollution hinder people's outdoor stay, which in a long-term perspective is a threat to public health (e.g., WHO, 2000). Indeed, access to greenery was identified as the key health-promoting design element in a recent state-of-the-art document on urban design and

human health. The Swedish environmental quality objective "A Good Built Environment" stresses that green spaces close to built-up areas should be protected in order to meet the need of recreational and physical activities and play. The EC-directive on environmental noise points to the need for protection of existing quiet urban areas (EC, 2002). The present project goes further; its aim is not preservation, but creation of new soundscapes in existing areas, using a sound-art approach.

Noise researchers have recently adopted the "soundscape approach" (e.g., Schulte-Fortkamp, 2002; Yang & Kang, 2005; Bottledooren, *et al.*, 2006). The applicants of this project have been leading in this development (Hellström, 2003; Nilsson & Berglund, 2006a). The traditional noise control approach focuses on the indoor sound environment, on adverse effects of noise (e.g., annoyance or sleep disturbance) and on single noise sources (e.g., road-traffic). In contrast, the soundscape approach focuses on outdoor sound environments, on positive effects of sound environments (e.g., psychological restoration), and on the total sound environment, all positive and negative sounds inclusive. This approach opens up the possibility of *adding* sounds in order to improve the sound environment.

PROJECT DESCRIPTION

Acoustic Design Artifacts

In this project, two types of acoustic design artifacts will be developed and evaluated in the laboratory, and then applied and evaluated in the field (full-scale applications in city-park and square). The design artefacts are described below in relation to previous research and practice.

(1) Dynamic Promotion of Qualitative Site Specific Sounds

The aim is to improve the soundscape by dynamic promotion of qualitative site specific sounds. This may be achieved by architectural strengthening of places in the park for social interaction, or by natural objects (e.g., fountains) or hidden loudspeakers (e.g., recorded bird song), which changes dynamically in order to optimize perceived soundscape quality. Research shows that most city-park visitors perceive external traffic as a negative and annoying part of the soundscape in city parks/squares, whereas sounds from nature (water, bird song, etc) are pleasant components of the soundscape (Ge & Hokao, 2005; Nilsson & Berglund, 2006a; Yang, & Kang, 2005). This suggests that the promotion of site specific sounds may counteract the negative effects of city noise. Anecdotal evidence exists of successful use of nature sounds in acoustic design (cf. Brown & Muhar, 2004). For example, sounds from water (fountains) may have a double function, both as provider of positive water sounds and as masker of unwanted city noise. However, scientific studies on the potential and limitations of promoting qualitative site specific sounds in noise polluted areas are lacking.

(2) Sound-Art Installations

Recently, sound-art installations have been introduced in some European cities (e.g., Urban Sound Institute, www.urbansound.org). The sound-art installation is an art object in itself. Its goal is to produce delimited sub-spaces, which interact with the remaining area. The effect of sound-art installations on perceived soundscape quality and on psychological restoration has not previously been empirically evaluated. The choice of aspects has as starting point that the public sound art genre is an interdisciplinary art form with its historical roots within concept and installation art, the expanded music concept and the soundscape movement.

RESEARCH ACTIVITIES

Overview

The project will develop, apply and evaluate a design methodology for acoustic design, applied to case studies of two specific outdoor open spaces, a city park and a city square. The methodology rests on a comparative study of a virtual representation (artistic, visual and acoustic) of a physical environment, validated in psychoacoustic studies of simulation (in the lab) and of the real environment (in the field). A real-time acoustic simulation system will be used, developed by one of the partners in the Uni-Verse project [Kajastila et. al.].

The following three fundamental aspects for dynamic promotion of qualitative site specific sounds and production of sound installations in public space concern:

1. Visual and architectural point of view
- what does the city-park/square look like, from a spatial, temporal and social point of view?
- what is the city park/square connection to the surrounding infrastructure and urban area?
2. Audible point of departure
- what constitutes the soundscape of the specific city park/square?
- what distinguishing qualitative site specific sounds are connected to the city park/square?
3. Interaction between art production and existing space
- what constitutes the audible interaction between the site specific sounds and sound installations with regard to the city park/square?
- what constitutes the visual interaction between site specific sounds and sound installations with regard to the city park/square?

The case study design process includes:

1. analysis of the city-park/square and its visual and acoustic parameters
2. construction of a virtual model, including acoustic parameters
3. redesign of site and its virtual representation
4. construction of the city-park/square

Psychoacoustic evaluation will be conducted at four different stages of the design process:

1. evaluation of physical site before redesign, in particular, measurement of perceptually relevant acoustic parameters.
2. evaluation of virtual representation in listening experiments
3. evaluation of acoustically redesigned virtual representation in listening experiments
4. evaluation of acoustically redesigned physical site in listening walks with panels and visitor questionnaires (cf. Berglund & Nilsson, 2006; Nilsson & Berglund, 2006a).

This overall process will be both input to and result of development of a design methodology for acoustic design. The evaluations will use a combination of acoustic measurements, listening walks and visitor questionnaires. Based on an analysis of these evaluations a comparative study will be made and conclusions on the relevance of acoustic simulation and predictability for acoustic design. These virtual representations will be developed during the first 18 months of the three year project, followed by full-scale application and field-study evaluation during the 18 month period, including final analysis of conclusions on the research question.

Selection of City-Park and City-Square for Full-scale Application

Discussions with the Stockholm City have already begun and a number of suitable city parks have been identified (*i.a.*, Mariatorget, Stigbergsparken, Medborgarplatsen and Norrmalms torg). Visitor questionnaire studies have been conducted in some of these parks, as part of a

joint project between the Stockholm City and the MISTRA-funded research program "Soundscape support to health" (data collection summer 2004 and 2006, see Nilsson & Berglund, 2006a).

Development of Acoustic Design Artifacts

1. Dynamic promotion of qualitative specific sounds

The project focuses on activities and elements that bring qualities to the city park/square, e.g., social activities, spatial and temporal qualities, existing artifacts (fountains etc) and birds. The main purpose is to distillate and strengthening these sound generating activities and elements in order to enhance the site specific qualities of the park. For instance, architectural elements comprising a double function as street furniture and noise barriers. Hellström has successfully experimented in full-scale with bird song from loudspeakers in central Paris (within the research project *Transmission*, funded by the Swedish Research Council 2005-06, www.urbansound.org). The feed-back system influencing the source (fountain or loudspeaker, including hidden high-directivity sound reproduction systems) will be driven by microphones responding to changes in the sound environment. These design artifacts may also intensify the social activities in the park, which would have a positive effect on the soundscape.

2. Sound-art installations

Installations will be developed which create auditory sub-spaces in order to strengthening the social interaction as well as the spatial qualities in the city park/square. The installations interact with the remaining area. A systematic analysis will be made in order to determine the spatial effects, i.e. regarding spatial orientation and variation. The installations are art objects, consisting of architectural elements that generate sounds electronically and/or mechanically. The goal is to create installations that fit into the visual context of the park and that create positive and restorative auditory sub-spaces of the park. The challenge will be to accomplish this by adding new artificial art-sounds to the noise-polluted soundscape.

Psychoacoustic Evaluation

The purpose of the psychoacoustic evaluation (listening experiments) is to determine how the acoustic design artifacts affect the perceived soundscape. The methodology rests on a comparative study of user evaluation of a virtual representation and of the physical environment itself. Soundscape recordings (binuaral recordings using artificial head and ambisonics) will be conducted in quiet areas and in noise-polluted areas, particularly in the city park and the city square chosen for field evaluation. Listening experiments will be conducted in existing listening rooms at Gösta Ekman Laboratory and University College of Arts, Crafts and Design. The experimental sounds will be combinations of binaural recordings of real soundscape and of auralizations. Recordings of quiet, undisturbed soundscapes will be systematically mixed with various types of sounds (e.g., bird song and sounds from water, electronic art-sounds from art installation, noise, human voices). The listeners will evaluate their soundscape perceptions, including perceived soundscape quality (see Axelsson *et al*., 2005), road-traffic noise annoyance, and perceived potential for psychological restoration.

Two series of listening experiments will be conducted (one per acoustic design artifact), each involving at least 30 listeners. Listeners of both sexes, 18-65 years of age will be recruited. Several of these will also be recruited for the listening panel in the field application (see below). Thus, the listening panel will have experience of soundscape evaluation and they will be

representative of typical listeners (panel members will be selected on basis of the reliability and validity of their assessments in the listening experiments).

Field-Study Evaluation

The effect of acoustic design artefacts on the city park/square soundscape will be evaluated by (1) listening walks (panel study) and (2) park-visitor questionnaire. An intervention study design will be used (cf. Nilsson & Berglund, 2006), that is, measurements will be conducted before and after implementation of acoustic design in the park and in control areas (part of the park not affected by the design or another park). Observe that several before-after studies are planned; each related to one type of acoustic design tool. This makes it possible to separately study the effects of each design tool.

(1) Listening walks

A panel of listeners will be recruited for soundscape evaluation in the field. The panel will be recruited among participants in the listening experiments (see above), N = 20-30 with a balanced gender and age composition. The panel will participate in several structured listening walks in the park, both before and after acoustic design implementations. The assessments will include sound-source identification, perceptual-emotional attributes, noise annoyance, psychological restoration and possibilities for speech communication. The listening walk protocol will be an improved and extended version of Berglund and Nilsson's (2006) protocol used for soundscape assessment in residential areas.

(2) Park-visitor questionnaire

Questionnaires will be administered to park visitors, both before and after acoustic design implementations (N>100). The questionnaire will be an improved version of questionnaires used in previous city-park studies in Stockholm (Nilsson & Berglund, 2006a). In particular, new scales of psychological restoration will be developed and included in the questionnaire. Previous questionnaire scales of the restorative potential of environments were developed mainly for visual scenery as presented in laboratories (e.g., Hartig, *et al*., 1997; Han, 2003). The improved scale will be designed for field use in city parks/squares, with a focus on the visual, as well as, on the sound environment. Other sections of the questionnaire will include questions on demographic factors (e.g., age, gender, residency nearby the park), and behavior (e.g., park use frequency/duration, reasons for visiting the park), and purpose of visit. The questionnaire will be pilot-tested for comprehension and acceptability during year 1-2 of the project. In addition to questionnaire responses, observational data will be collected as indicator of park quality. During randomly selected time periods before and after acoustic design measures (e.g., 4 hours in two randomly selected weekdays), park entrances will be observed and the number of visitors will be counted.

SUMMARY

The strongest reason for carrying out the present project is the need to find ways for creating pleasant and stimulating soundscapes in noise polluted urban areas. For this to happen, new research approaches have to be explored. The present project beat a new track by combining *acoustic design* with *sound art research,* integrating methodologies based on *real-time acoustic simulation* and application of *psychoacoustic methodology* for validating simulations and for evaluating perceptual, emotional and behavioral effects on visitors to public open spaces.

If successful, the project will demonstrate how to apply acoustic design in order to improve urban outdoor spaces. The case-study applications may serve as models for future applications of acoustic design in urban outdoor spaces.

The project is innovative, because it confronts the problem of noise pollution in outdoor areas from a design and art perspective, not from the conventional noise control perspective. The project also introduces and evaluates a methodology based on real-time simulation. Furthermore, the project challenges the visual dominance in urban planning, and is therefore highly relevant to urban research in general.

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