A Soundscape Assessment Tool Based on a Massive Multichannel Loudspeaker Setup

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Summary

This paper is twofold: 1) it describes a comparative study between two listening tests methodologies and 2) presents a new soundscape assessment tool based on a multichannel loudspeaker setup and sonic interaction. The goal of this research is to enhance soundscape assessment methodologies by improving the quality and validity of laboratorial testing. Our proposal builds upon the concepts of “ecological validity” of auditory stimuli and “representative design” of the listening experience, both introduced by [1] in the context of psychological experiments on perception. Results suggest that representative design (mimicking real-world settings in laboratory) in soundscapes listening tests is better achieved through surround systems than binaural systems (using headphones). Moreover, users agree that the interactive system for real-time soundscape design helps raising awareness for the soundscape and auditory phenomena.

1 Introduction

Soundscape is a term coined by Murray Schaffer as a synonym of “sonic environment” [2]. However, this term is also used to express a new positive attitude towards the sonic phenomenon, assuming sound as a resource rather than a waste. This perspective implies the enrolment of the listener on the assessment of a sonic environment, since the focus is no longer on the sound itself but rather on how people perceive it. Therefore, it requires the contribution of a large number of disciplines to fully comprehend the phenomenon, including – but not limited to - Psychology, Philosophy, Anthropology, Cognitive Science, Sociology, Acoustics, Composition, Sound Design, Physics and Biology.

Regarding noise pollution issues, some specialists [3–5] have followed Schaffer's footsteps and proposed solutions based on a soundscape approach, as an alternative to *deaf* solutions such as Community Noise [6]. They state that sonic welfare is not achieved exclusively by keeping noise levels down but by assessing how different communities understand and relate to their sonic environment, by identifying meanings, patterns and dynamics. In order to follow a soundscape approach for the mitigation of noise annoyance problems and promote the development of friendly sonic environments, measuring sound pressure levels is only one side of the process. The other side is accomplished through listening tests, using people to assess different dimensions of a soundscape.

This paper addresses the methodology for laboratorial listening tests and suggests ecological validity as a key element for its success.

1.1 Listening Tests

Soundscape studies make use of listening tests as a common research tool to assess and evaluate several dimensions of soundscapes, such as quality [7], annoyance [8] or loudness [9]. Listening tests can be accomplished in different ways and formats, depending on the circumstances and aims of the experience. They can be done in situ – in the actual scenario, in presence of the original soundscape being assessed - or in laboratory, where the sonic environment is recreated artificially.

Listening tests *in situ* are usually preferable but not always possible, since some studies consider non-real places or focus on particular dimensions that demand artificial manipulation (e.g. *auralization*). Typical approaches include sound walks [10], where listeners walk through a place describing/evaluating its soundscape or narrative interviews to people who are/were at the place [11].

Listening tests in laboratory are usually easier to control but they lack the sense of realism observed in *in situ* tests, both because of the artificial scenario and artificial acoustics provided by the playback systems. Typical approaches for this type of tests include headphone listening (stereo and binaural recordings or synthesis), listening to real sources brought into the lab [12] and listening through loudspeakers (usually with a limited channel count) [13].

Listening tests are normally complemented with a questionnaire or other survey method.

1.2 Representative Design and Ecological Validity

The lack or realism observed in perception tests occurring in a laboratory may compromise the legitimacy of the experiments, hindering scientific truth. This idea is expressed in [1] where the author presents the concept “representative design” as preparation for experimental conditions according to behavioral setting to which the results are intended to apply. That is, to approximate the laboratory situation to the real environment as far as possible, without oversampling improbable variables. This approach defies classical approaches where interference from the environment should always be avoided in order to optimally assess the proper variable. According to [14] this position was firmly defended, inter alios, by Helmholtz or Wundt.

In turn, “ecological validity” is a concept also introduced in [1] to define the correlation between a perceptual cue and the distal variable to which it is related. For example, it defines how much an auditory stimulus can assist in identifying the actual source (or other variable: position, loudness). In [15] Gibson presents an ecological approach to visual perception and defends that “The laboratory must be like life”. However, this concept is often misused in scientific literature as a synonym for “representative design” (see [16] and [17] for a discussion).

We see as necessary the use of representative design experiments to assess soundscapes in laboratory, since the definition of soundscape is highly dependent on the idea of environment and context of action. Therefore, it is important not only to match the acoustic environment of the original location by recreating other stimuli considered relevant for the variable being studied. For example, studies have demonstrated the influence of visual stimuli on listening (and vice-versa), stating that what we see influences what we listen to and how we listen ([18]).

In the following experiments, in order to diminish visual bias and accomplish a representative design for the listening tests we have recreated not only similar acoustic stimuli but also coherent visual cues of the soundscape’s original place.

2 Experimental Procedure

In order to provide an answer for the stated problem, an experiment was conducted involving listening tests with 25 subjects. The experiment was divided in two parts: *Part I* - a comparative study between two sound reproduction systems; *Part II* - user test for an interactive soundscape design tool.

2.1 Overview

The soundscapes used in the listening tests were recorded at a university cafeteria, on a Friday, between 12h and 13h. The cafeteria was showing light activity (some meals were starting to be served), with an occupancy rate around 25%. The place is approximately 110 m^2; ceiling height of 4m, stone walls and tiled floors. It contains 15 tables and 40 chairs. It is a highly reverberant space and the noise of chairs dragging on the floor plus chatting makes it a boisterous place at peak hours.

The experiment took place in a former warehouse recently converted into a MoCap studio, equipped with a multichannel surround system of 16 discrete speakers (Genelec 6010A). The room area is approximately $75m^2$, with stone walls, concrete floors and minor acoustic treatment (black flannel curtain converging the surrounding walls). Though not measured, subjective analyses indicate that the reverberation time is shorter than the cafeteria.

In order to follow a representative design approach, by giving a sense of the place represented in the listening test, some of the cafeteria conditions were replicated at the experiment set. Subjects were sitting at a cafeteria table with some dishes and a soft drink can on top. A large canvas was suspended in front of the subjects, to receive a video projection (Figure 1 - Left). The video consisted of footage from the cafeteria, recorded from the point-of-view of a person sitting at one of the tables. This way, subjects participating in the experiment where looking at a real-size video image of the cafeteria, matching the perspective of someone actually sitting there.

Previous studies [13] reported that seeing the speakers would influence how people perceive the sound. In order to avoid visual bias the room was darkened, featuring only one spotlight hanging on the celling, pointing down at the subject’s table (Figure 2).

2.2 Subjects

Twenty-five sets of listening testes and questionnaires were conducted. Subjects were college students or university staff, aged from 20 to 37, who agreed to participate without payment. All participants were familiar with the cafeteria.

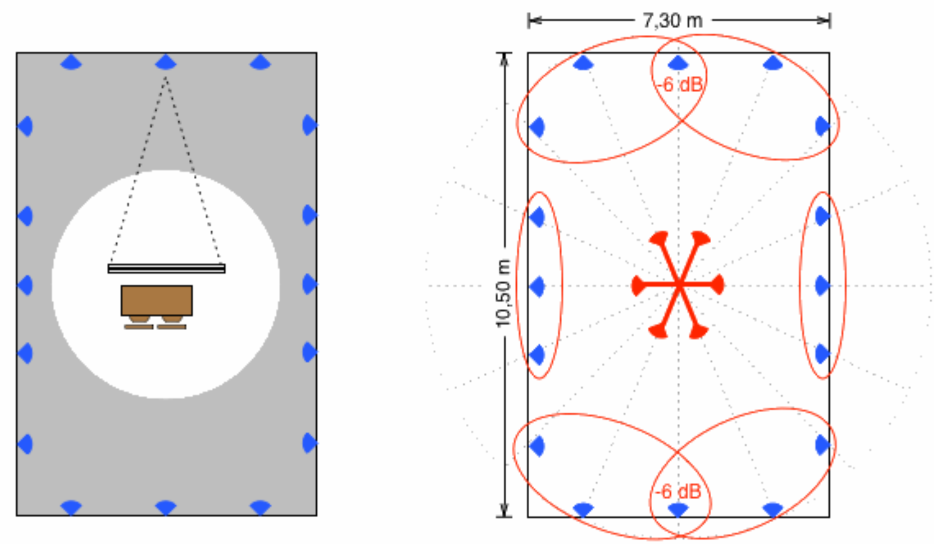

Figure 1. Experiment room plan. Left: table, canvas and spotlight. Right: microphone array arranged according the speakers' distribution (red cross in the center), speakers (blue) and signal distribution (red ellipses, one for each channel/microphone).

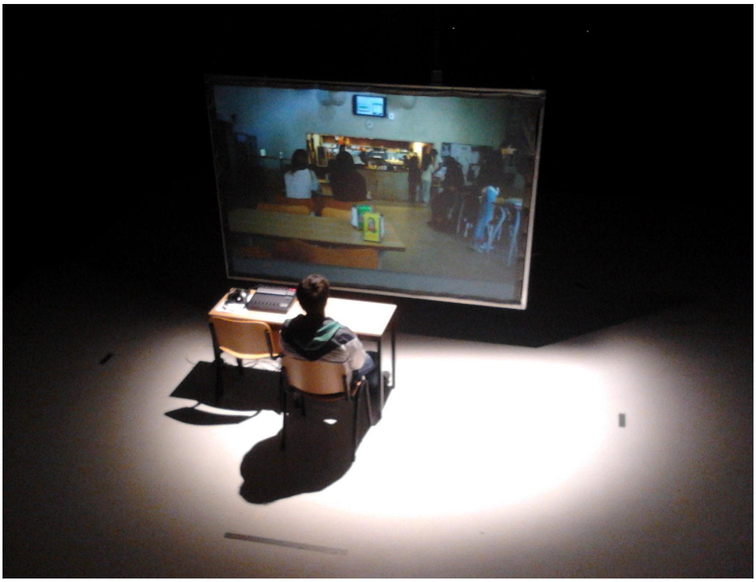

Figure 2. Experimental setup.

2.3 Part I – Binaural vs. Surround

2.3.1 Method

In Part I we compared two sound recording/reproduction systems: binaural and surround. Both audio recordings were accomplished at the same time and location using two different methods (described next). Each sample was two minutes long. Subjects listened one after the other with approximately 20 seconds interval. The two samples were played in random order to avoid a sequence bias. While the sound was playing, subjects were asked to engage in leisure activities, such as reading a magazine or playing a tablet game (neither activities demanding the use of audition). The goal was to distract the subjects, avoiding attentive listening and promoting background listening. After the listening test, subjects were asked to answer a structured questionnaire orally, which aimed at characterizing their listening experience, including their preference regarding the two systems.

Sound pressure level was regularly measured during the recordings (SPL – C-Weighted).

2.3.2 Binaural setup

The binaural recording was made using two omnidirectional blocked ear canal microphones. We preferred this technique based on [19] research and empirical tests comparing it with a DIY dummy head available at the moment of the test. A research assistant was sitting still at a table wearing the microphones, a video camera was recording footage from his point-of-view (subjective camera) and a sound recorder device was capturing the sound from the microphones.

During the test, participants listened to the binaural recording using a pair of closed-back circumaural headphones (Sennheiser HD320). Subjective measurements were made to match the reproduction pressure level with the sound pressure level measured during the recording session.

2.3.3 Multichannel setup

The multichannel recording was made using an array of six cardioid, small capsule, condenser microphones. The arrangement of the microphones was based on the IRT Cross [20] (also known as “atmos cross” for being suited for recording ambient sound). We have decided to expand this technique by adding an extra pair of microphones, since our reproduction system had sixteen discrete speakers instead of the usual five or seven found in commercial surround systems. Moreover, the angles of the microphones were setup having in mind the placement of the speakers in the reproduction room (Figure 1).

The reproduction of the audio files (six channels) was done using a setup with sixteen speakers (described before). The system was previously calibrated and followed the signal distribution mention in (Figure 1 - Right), using custom-made software[1], which handled the distribution of de signal, including phase delays. The volume of the speakers placed in front of the listener (behind the canvas) was 3dB louder, to compensate for the sound blockage caused by the video canvas. Since all the speakers were playing slightly different signals, a rich sound field was achieved. No subwoofer was used.

2.3.4 Results

When subjects were asked to identify the listening experience that more closely matches the real situation, from an auditory perspective, 48% chose the surround system, 40% the binaural system and 12% felt no difference. When subjects were asked the same question but focusing on the global experience, the answers were: 60% for the surround system, 36% for the binaural system and 4% did not feel any difference (Figure 3).

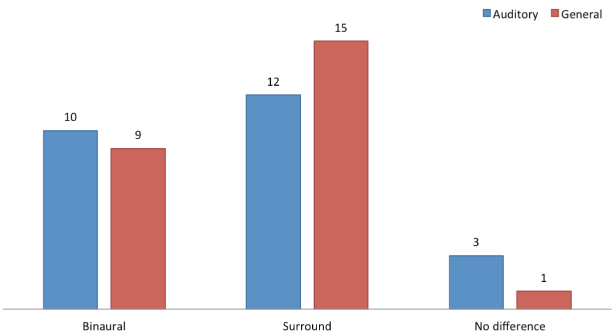

Figure 3. Subjects preferences regarding the auditory and overall experiences, with binaural and surround systems (number of responses).

The following question was about the reasons of their choice regarding the overall experience (it was a closed question allowing multiple choice). The reason that stood out was the “sensation of space”, while all the other

[1] Software was programed in Max/MSP 5 and adapted the spatial audio external Ambimonitor by Philippe Kocher and Jan Schacher (www.icst.net).

reasons were represented roughly equally and far below the most popular. In order to better understand this data we analyzed the answers separately for the subjects who selected the binaural system and the surround system. Those who chose the surround system clearly did it due to “the sensation of space provided” and “free from headphones use”. Those who chose the binaural system were not so assertive choosing their motivations, pointing out several other reasons related to the auditory experience, such as “better source localization”, “more immersive”, “higher sound fidelity”, “higher sound quality” and “more natural” (Table 1, Figure 4).

Reasons	Both resp.	Binaural	Surround
Headphones free	6	0	6
Sense of space	18	7	10
Fidelity	9	6	3
Immersiveness	8	5	3
Naturalness	5	3	2
Source localization	9	5	3
Sound quality	6	4	2

Table 1. Reasons why subjects chose binaural/surround as the most global real experience (number of answers).

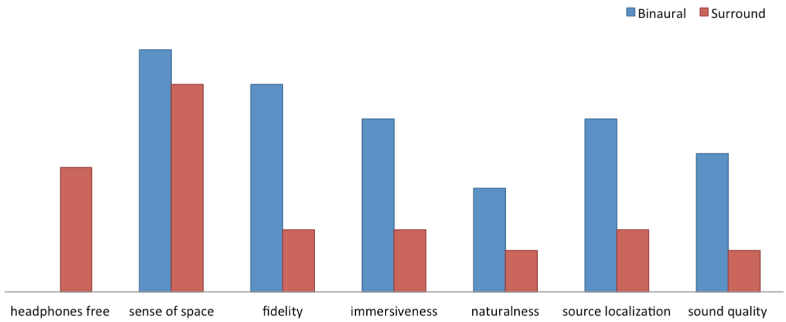

Figure 4. Reasons why subjects chose binaural/surround as the most global real experience (normalized values, just for visual comparison).

2.4 Part II – Soundscape Designing Tool

2.4.1 Method

Typically, soundscapes and noise control studies are based on listening tests followed by structured questionnaires or free interviews, which are then analyzed through linguistic exploration of verbal data. In experiment’s Part II we have ran preliminary tests to assess a methodology based on active design of soundscapes and semi-structured questionnaires. After responding to Part I questionnaire, users were invited to create their favorite soundscape for the cafeteria. To accomplish the task, custom-made software was designed to accommodate four audio tracks, each one bearing four 6-channel surround samples of the same sound category (dialogs, radio/tv, nature, cafeteria). The system allowed the user to select one sound for each track/category and change its volume (a typical audio mixing process). No GUI was used; subjects interacted with the system using a tangible MIDI controller[2]. The sounds were reproduced using the surround system described before.

2.4.2 Results

After creating their favorite soundscape, participants were asked to rate from 1 to 5 (nothing to very), how much this type of exercise contributed to raise their awareness for the sound environment (Figure 5). Measurements of SPL for each submitted soundscape showed that the average level from all participants is 72,9dB (C-Weight, slow response), roughly 2dB lower than the levels measured in the cafeteria during the experiment.

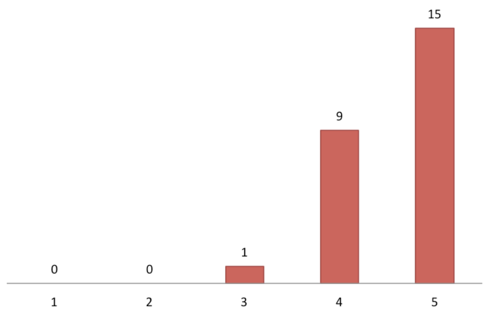

Figure 5. Evaluation of the exercise regarding its ability to promote environmental sound awareness.

The last question asked for a comment on the experiment. In general, participants enjoyed doing the experiment since it provided them with the opportunity to listen to the same sound in different formats. Furthermore, the system for soundscape design allowed them to think and “craft” the sound for a place, which was something that most of the subjects had never thought about. Some subjects also pointed out the effectiveness of the real-size video canvas in providing a sense of place.

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[2] Behringer BCF2000

3 Conclusions

Part I: A comparative study between binaural listening and a massive multichannel surround listening was done, using the soundscape of a cafeteria as testing material. The results showed that participants are divided as to which system is able to deliver the most realistic auditory experience but elect the surround system as the one able to provide the most global realistic experience. Paradoxically, both participants pointed "the sense of space" as the main reason for their choice, which lead us to conclude that this concept is problematic, since it does not mean the same for every person, and it should therefore be avoided or previously explained to subjects in future tests. Further analysis revealed that participants who choose the binaural system, do it for its good auditory properties (fidelity, quality, localization) while those who choose the surround system, privilege the fact that they do not have to wear headphones, over the argument of sound quality. Therefore, from the overall results, we conclude that in listening tests on soundscapes, it is preferable to prioritize the use of surround systems over headphone listening. It provides better sense of reality, which moves towards the representative design approach.

Part II: An interactive system for soundscape design was tested with the massive multichannel speaker setup. Users agreed on the potential of the system to promote sound awareness among people. We believe that this methodology based on sonic interaction provides a better way to communicate about sound with non-experts, since it eliminates the linguistic intermediation, which is error prone (as demonstrated before during this study). Therefore, it should be considered in soundscape studies as a complement to traditional listening tests and questionnaires.

4 Further Research

In the long run we envision an upgrade to the system, consisting of the accommodation of video projection on three surrounding walls and the addition of six speakers mounted on the ceiling pointing down, creating a dome-like setup. Consequently, future research will explore different multichannel recording/reproduction techniques, in order to increase the ecological validity improve representative design methods in soundscape assessment.

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