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Interactive soundscape augmentation of an urban park in a real and virtual setting

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ABSTRACT

Inappropriate soundscapes are able to strongly deteriorate the user experience in parks. A possible remediation is adding positively perceived sounds. The case of an urban park, fully surrounded by road traffic noise sources, was studied to explore the potential of adding natural sounds in an interactive way. A preliminary test was conducted in the lab with Virtual Reality (VR) glasses and headphones. The audio-visual representation of the real environment was obtained by combining binaural recordings with first-order ambisonics and 360-degree video camera footage. The users were allowed to mix in eight types of natural sounds until their personal optimized soundscape was composed. This was done in a very similar setup as in the (real) park. The loudspeaker augmenting the sound environment in the park was steered with a smartphone application. This app ensured the user's presence near the loudspeaker and allowed to gather more detailed assessments of the perceived sound environment through questionnaires. This combination of experiments allowed checking the validity of VR that is becoming increasingly popular in audio-visual interaction studies. In addition, the most preferred natural sounds and the way they influenced environmental noise perception were analyzed.

Keywords: Soundscape, Virtual Reality, Augmented Reality.

1. INTRODUCTION

When well designed, urban parks are able to provide multiple ecosystem services. Of major importance for people living in city centers are the social and health related benefits (1). However, these can be jeopardized by excessive or inappropriate sound exposure. Especially the abundance of mechanical sounds in cities might strongly deteriorate these services for citizens.

Sound levels inside parks could potentially be mitigated in a natural way e.g. by placing dense tree belts near the borders (2) or by so-called "acoustical landscaping" (3). However, this conflicts with many design criteria for the other park functions; visually dense or non-transparent parks might e.g. give rise to perceived unsafety (4).

An alternative is relying on the soundscape idea (5). Instead of trying to mitigate unwanted sounds, positive sounds are added. Obvious candidates in park environments are natural sounds. In this study, various types of bird sounds, insects, water sounds and meteorologically induced sounds have been considered. The question remains what types of sounds and what combinations are most suited and preferred by the park visitors. The latter was studied in an interactive way.

Virtual reality is increasingly becoming popular in landscape and city planning. The question remains, however, to what extent a park experience can be captured. In this work, this research question is narrowed down to analyzing whether the preferred natural soundscape in a virtual setting is similar to the one found in the real park.

The case of interest is the Zuidpark in Gent (Belgium), an urban park with an open character, surrounded by intense road traffic. Continuous sound pressure level measurements during 5 months showed an L_{den} value of 62.6 dBA. The L_{day} indicator in this same period equaled 60.4 dBA.

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2. VIRTUAL REALITY (VR) EXPERIMENT

The audio-visual representation of the park environment is based on a combination of binaural recordings with first-order ambisonics and 360-degree video camera footage (6). For visual representation, an Oculus Rift was used. The environmental sounds from the park were reproduced with an open headphone. The setup allowed to mix in the natural sounds played by a loudspeaker that was positioned roughly at the same height and distance as in the real park environment. The participants could control a mixing panel (with mechanical sliders) while composing their preferred soundscape based on the eight available natural sound samples. This test was performed in a semi-anechoic room as shown in Fig. 1. In this preliminary test, the number of participants were limited to 10.

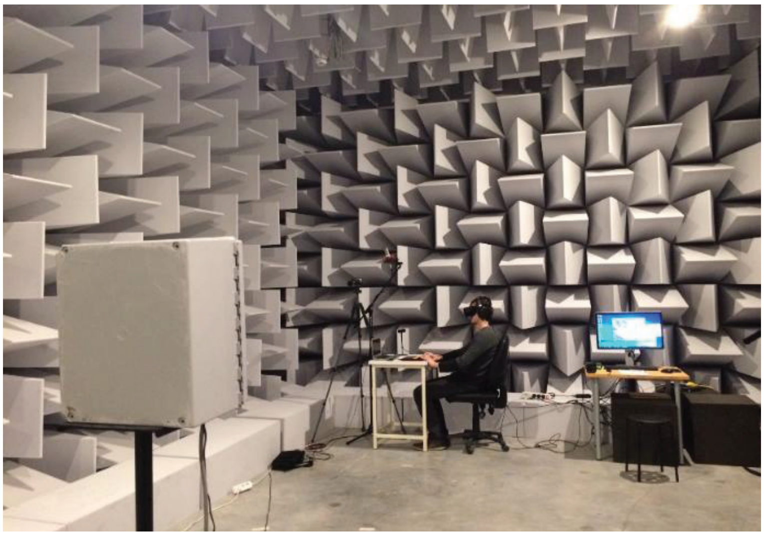

Figure 1 – Experimental setup for virtual reality experiment in the semi-anechoic room.

3. AUGMENTED REALITY (AR) EXPERIMENT

In the real park, the loudspeaker was hidden from sight by the vegetation (see Fig. 2). Participants were instructed to move to a specific zone close to the single-board computer (SBC) operating the loudspeaker. The experiment could be accessed at any moment during the day hours and – in theory - no instructor guiding the experiment was needed.

Environmental sound pressure levels were continuously monitored close to the loudspeaker box. This will allow a more thorough analysis of the interaction between the soundscape composition and the momentary (background) sound field.

3.1 Android app

Interaction with the loudspeaker box was performed by an Android app on the personal smartphone (see Fig. 3). The SBC served as a local Wi-Fi access point. This connection allowed to control the loudspeaker and to log the answers to the questionnaires and other usage statistics. When the participant went outside the range of the Wi-Fi access point, the session stopped. This principle confined the participants to a limited zone and ensured that they could actually hear the sounds played.

3.2 Tasks and questionnaires

The smartphone app not only served as a mixing panel to augment the sound environment with natural sounds, but also for sending a number of small questionnaires to the respondent.

First, each participant was instructed to listen to the current background noise for at least one minute. Next, a question was asked regarding the general appreciation of the sonic environment, some specific soundscape related questions (5), and also to what extent specific environmental noise sources could be heard.

Secondly, the user was asked to rate a random soundscape, previously composed by another participant. The minimum listening time was set to 1 minute. The same set of questions related to the background noise was asked afterwards.

Thirdly, the user was invited to compose their own preferred soundscape for the current environment. The natural sounds that could be added (using a software mixing panel, see Fig. 3) were not named as some might have a positive or negative connotation. When finished, the volume settings were stored on the SBC, and the soundscape was added to the database and could potentially be presented to future users.

Figure 2 –Designated location to participate in the interactive soundscape experiment in the (real) park.

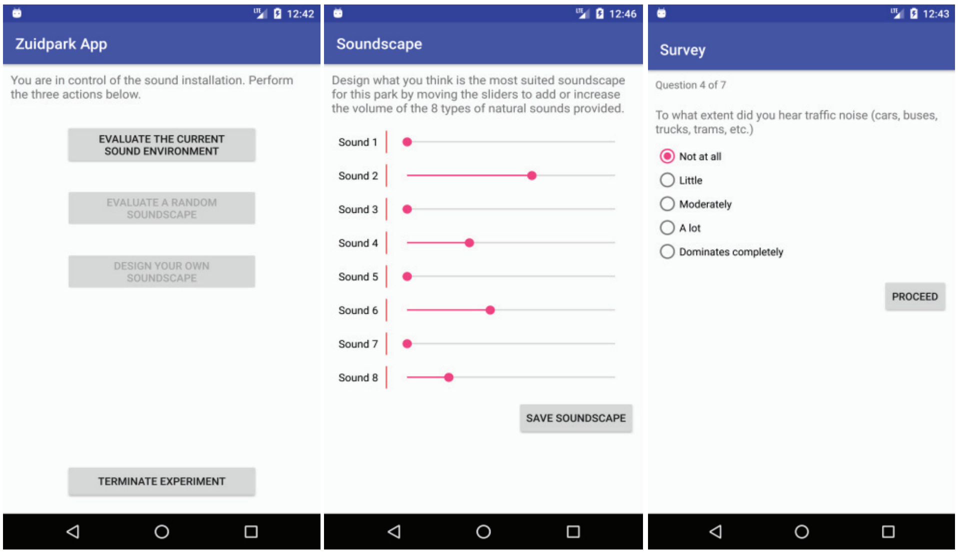

Figure 3 – Some screenshots of the soundscape smartphone app.

4. RESULTS

4.1 Preferred soundscapes

The current analysis is based on 58 participants that successfully finished a complete session in the park (see Section 3.2). The average volume setting (between 0 = mute and 1= maximum level), over all participants, is shown in Fig. 4. Although such preference inevitably leads to rather large interpersonal variation, some clear trends can nevertheless be observed. Bird sounds, more specifically “song birds mixture” and “house sparrows”, are the most preferred natural sounds in the urban park. This is consistent with older research (see e.g. Ref. 7). “Sea gulls”, in contrast, are much less wanted, probably by a bad connotation and being less congruent with the current environment (no nearness of the sea-side). The "waterstream" is somewhat more preferred than the "falling water" (consistent e.g. with Ref. 8). "Rustling leaves" and "raindrops on vegetation" are less chosen, probably given that their spectrum is more noise-like and coincides too much with the background noise. The bird sounds, in contrast, operate in a frequency range (3-6 kHz) that easily reaches a good signal-to-noise ratio in the park. In addition, these sounds are intermittent and thus more easily attract attention (9).

The preliminary test (with 10 participants), based on a virtual representation of the same spot in the park, gives a more or less similar averaged set of volume settings (see Fig. 4).

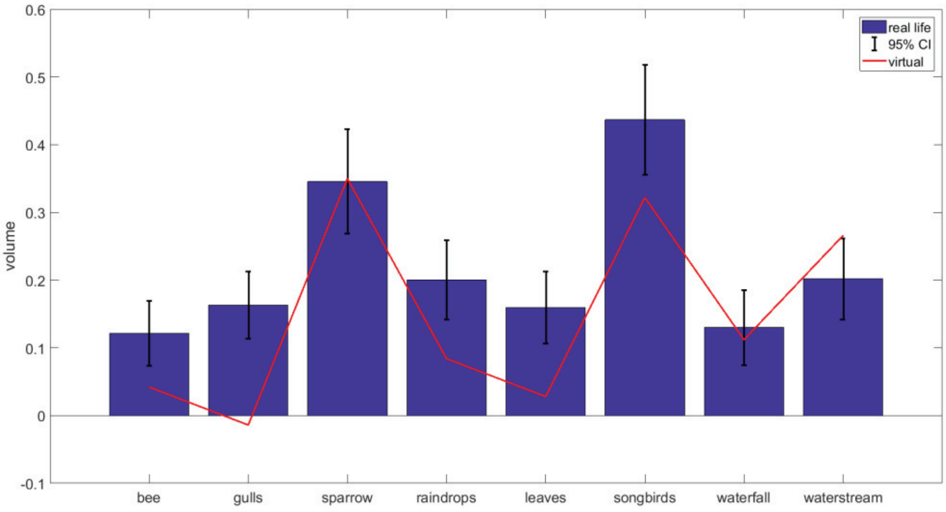

Figure 4 – Averaged volume settings of the composed soundscapes over all participants. The error bars indicate the 95% confidence intervals on the means, assuming a normal distribution of the data. For comparison, the red line indicates the averaged channel volumes in the VR experiment.

4.2 Effect of soundscape on general appreciation of the sound environment

The use of soundscapes to improve the acoustic environment is analyzed by subtracting the rating after listening to the background noise from the rating after being exposed to a random soundscape. Such a relative comparison removes interpersonal differences in absolute rating level, strongly increasing the power of the statistical analysis.

For the absolute scales, the following categories were used in the survey ("How would your rate the sound environment you just experienced?"): 1="very bad", 2="bad", 3="neither good nor bad", 4="good", 5="very good". For the pairwise differences, 0 means staying in the same category, e.g. +2 means jumping over 2 classes (e.g. from "bad" to "good"), and -2 resulting in a worsened situation. Figure 5 depicts the histograms showing the absolute (left, middle) and relative (right) ratings.

The overall appreciation of the sound environment is on average improved by any natural soundscape with 0.6 units. This improvement is statistically significantly different from 0 (t_{56}= 3.5189; $p<0.001$) with 95% confidence intervals between 0.26 and 0.94.

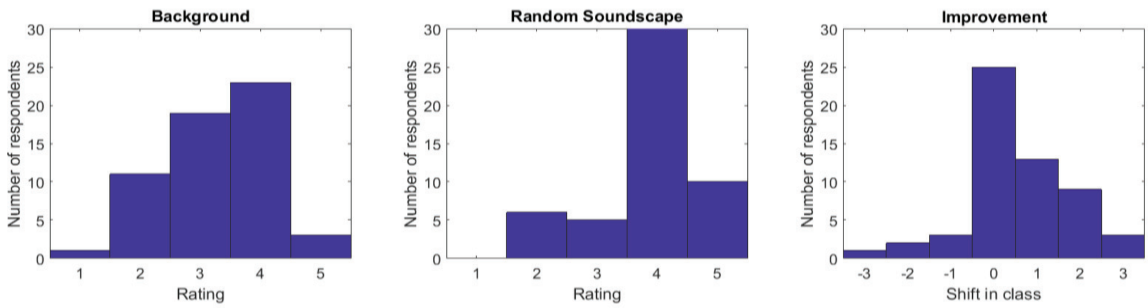

Figure 5 – Histograms showing the general evaluation of the sonic environment.

4.3 Effect of soundscape on hearing traffic noise

A similar analysis (see Fig. 6) was performed for the question to which extent traffic noise was heard. Again, a 5-point scale was used, with 1=”not at all”, 2=”a little”, 3=”moderately”, 4=”a lot”, 5=”dominates completely”. Because of the soundscape, a shift of 1.33 units towards less hearing traffic was observed in a paired t-test (t_{56}= 8.961, p<0.001). The 95% confidence interval ranged from 1.04 to 1.63. These results show that augmenting the current environment with a natural soundscape has a strong masking potential on road traffic noise.

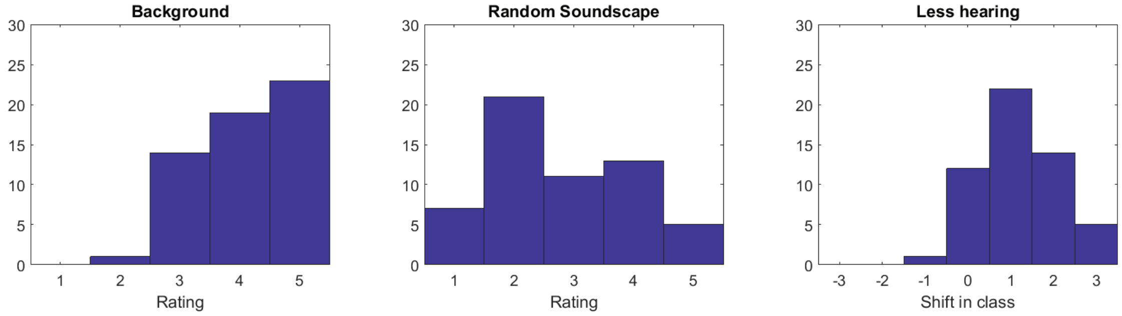

Figure 6 – Histograms showing the degree at which traffic noise is heard.

5. CONCLUSIONS

In this study, the preferred soundscape composed of eight natural sounds, in a highly road traffic noise polluted urban park, was assessed in an interactive way in VR and AR. The results show that the optimized soundscapes mainly contain bird sounds in both the real and virtual representation of the park. Additionally adding natural sounds improves the overall appreciation of the sound environment in the park, and strongly enhances road traffic noise masking.

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