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Effects of combination of water sounds and visual elements on the traffic noise mitigation in urban green parks

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ABSTRACT

During the last decade, several studies have demonstrated the potential role that urban green parks may have on restoration and well-being for people who live in dense urban environments. On the other hand, measurement campaigns and survey in different urban parks have also showed how their soundscape may be significantly affected by road traffic noise, or other surrounding noise sources.
While classical noise mitigation interventions with screens or noise barriers are often not compatible with urban contexts, especially in case of strong landscape values, the introduction of natural sounds has been found to have a general positive effect in enhancing the overall quality of acoustic environments.
The study presents the results of a laboratory test in Immersive Virtual Reality, where different solutions with water's sounds, used for the informational masking of traffic noise, and some associated visual objects were combined in virtual scenes. The test was administrated to a sample of participants in order to assess the effects on soundscape quality and its attributes.

Keywords: informational masking, visual influence, urban parks, noise mitigation, restorativeness
I-INCE Classification of Subjects Number: 52.3, 56.3

1. INTRODUCTION

Green neighborhood's spaces and urban parks represent, for citizens and visitors, places for recovery of psychophysical capacities and for relaxation. Within existing cities, these places are often located in dense urban areas where they are easily threatened by the surrounding road traffic noise and by other noisy activities.

With the Directive 2002/49/EC, the European Parliament has roughly defined the quiet areas and indicated the need to preserve them in urban agglomerations [1]. However, the traditional solutions to mitigate these areas from traffic noise (e.g. screens, noise barriers, reduction of traffic volumes) are too complexes or often not achievable.

On the other side, several researchers have studied the related aspects of informational masking [2] in order to improve the acoustic comfort of urban spaces. Yang & Kang have observed that by introducing a pleasant sound it can be considerably improve the acoustic comfort of urban open spaces, even when its sound level is rather high [3]. In particular, natural sounds were found to be related to a positive perception of the urban soundscape [4]. Among them, water sounds have showed to be the preferred natural sounds as masker of urban noises [5], but also to have effects on the reduction of loudness [6] and on the improvement of the perception of tranquillity [7].

A very important role is played by the acoustic character of the water sounds, in fact, highly pleasant water sounds may increase the overall pleasantness of the acoustic environment [8]. Good results may be obtained using water features generating natural sounds rather than sounds that appear more artificial or man-made [7]. Jeon et al. [5] found that water sounds such as “stream” and “waves of lake” were effective natural sound to mask urban noises.

Regarding the level of the masking sounds, despite some effects were already observed at -7 dB [7] below the road-traffic background noise level, the researchers agree to establish that the masking sounds should be similar to or not less than 3 dB [5,9].

With regard to the visual aspects and their influence on the perception of the environment few

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studies have been carried out.

Jeon et al. [10] have shown through laboratory experiments with “only audio” and “audio-visual” stimuli that the soundscape preference is influenced by both the acoustic characteristics of the water sounds and the visual aspect of sources. Comparing uni-modal (only audio and only video) and bi-modal (audio-visual) perception, Galbrun et al. [11] highlighted that equal attention must be given in the design of both stimuli and that the addition of visual or auditory stimulus rarely leads to a statistically significant change in preference scores.

The aim of this preliminary study is to understand how combination of audio and visual characteristics of installations with water features, which can be used for informational masking of traffic noise in urban parks, may influence the perception of the environment and the components of the Restorativeness.

2. METHOD AND MATERIALS

A laboratory experiment was organized in an Immersive Virtual Reality environment. Five scenarios with congruent combinations of audio and visual elements were prepared. The scenarios, without (one control scenario) and with installations with water features (four scenarios), were presented to a sample of subjects to compare subjective evaluations of the urban park's Restorativeness and of the environmental quality. Starting from a basic scenario (control) which represents an urban park surrounded by road-traffic background noise without any kind of installation with water features, four more scenarios were prepared. These scenarios combine two different level of the auditory factor, each one with two congruent levels of the visual factor.

The two levels of the auditory factor were characterized by: 1) road-traffic background noise with an additional water sound of a river; 2) road-traffic background noise with an additional sound of sea waves.

The two levels of the visual factor were: 1) the initial urban park (control) with an installation with water features of small size and a regular shape; 2) the initial urban park (control) with an installation with water features of big size and a surrounding shape.

2.1 Auditory Stimuli

Recordings of the background noise produced mainly by road-traffic have been carried out within an existing urban park. The recordings were carried out by means of a Zoom H6 recorder equipped with a Soundfield SPS200 microphone (Fig. 1 - left). Contemporary, to determine the sound equivalent level during the recordings a sound level meter “Solo 01-dB” was positioned close to the Soundfield microphone. The recordings in B-format were then processed by means of the plug-in “Surrounding Zone” for playback in a 5.1 surround system setup. The playback system includes 5 loudspeakers (Dynaudio BM5A MKII) and a subwoofer (Dynaudio BM9S) drived by a sound card Motu 828 MKII. The system was installed in the anechoic chamber of the Department of Architecture and Industrial Design of the Second University of Naples. The playback system was calibrated in order to reproduce at the centre of the anechoic chamber the same sound equivalent level of 58 dB(A) measured in situ (Fig. 1 - right).

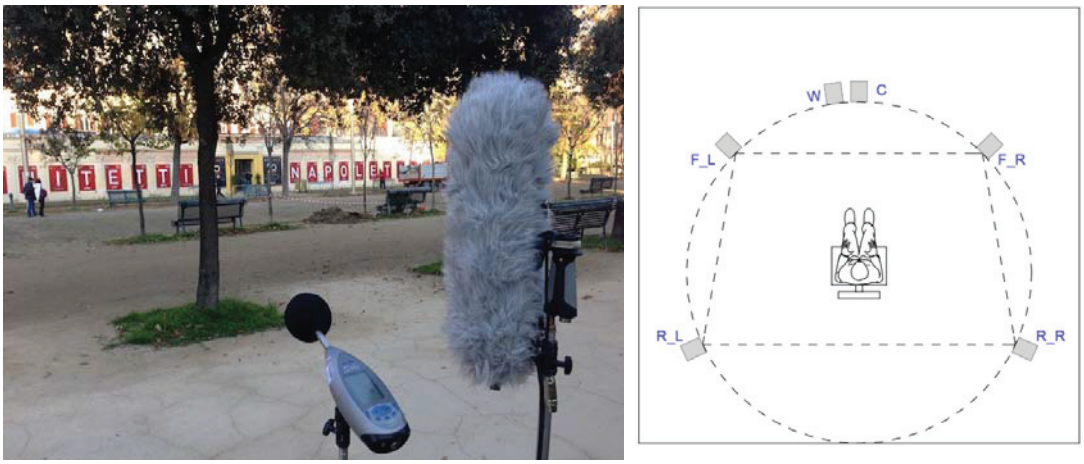


Figure 1 – Left: In situ recording; Right: Scheme of the playback system (right).

The two most effectives [5,12] maskers sounds reproducing water stream and sea waves were selected from an online sound databases. As suggested by literature [5,9], they were reproduced at a sound equivalent level of 55 dB(A), 3dB lower the road traffic background noise.

2.2 Graphical Stimuli

A three-dimensional reconstruction simulating an existing urban park was prepared with a 3d modeling software. The model has been mapped and optimized and finally implemented into Unreal Engine (Fig.2). The model includes several objects: roads, cars, trees, flowerbeds, gardens, benches, lamps, people.

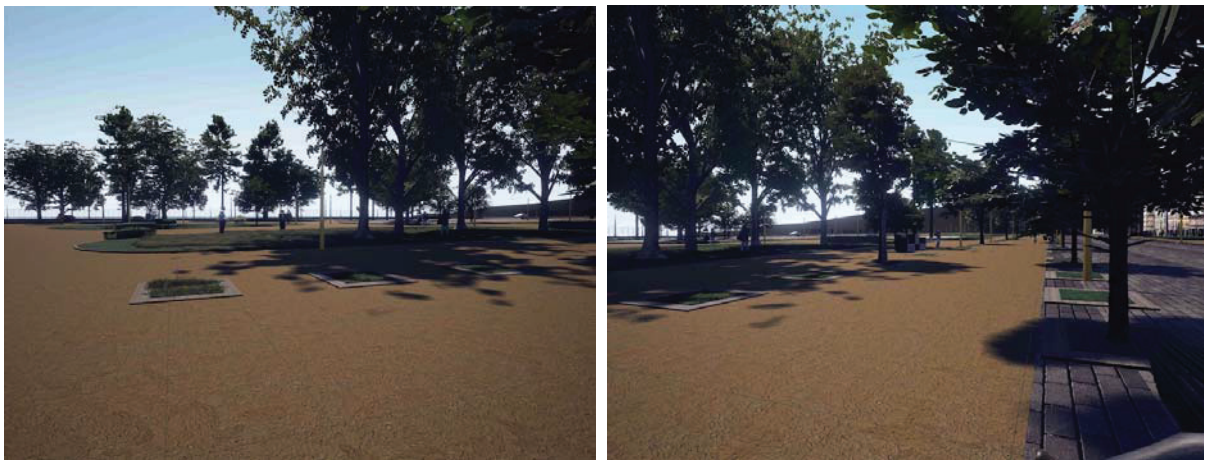


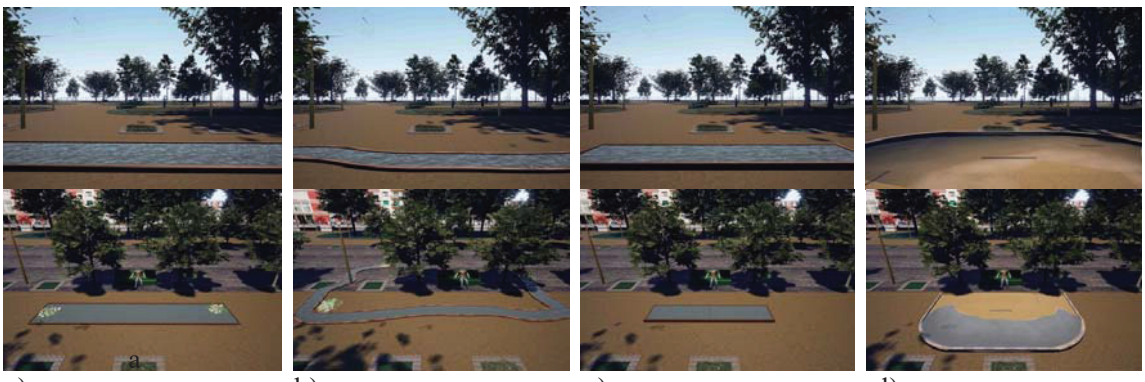
Figure 2: Two views of the control scenario.

Subsequently, four types of installations with waters features were designed and used in the virtual environment. Two installations were visually coherent with the sound of sea waves and two visually coherent with the sound of river.

The differences between the pairs of installations having the same water sounds were: the size (as extention from point of view of the subject) and shape (regular or surrounding the position of the subject).

The four graphical models (Fig.3) are shortly described below: a) A rectangular tank in which the water flows in a single direction, like a portion of river; b) A wide installation which simulates a sinuous river surrounding the bench where is positioned the subject; c) A rectangular tank where the water moves according to a swinging motion; d) A wide installation which simulates the motion of sea waves on the waterline.

The visualization and the exploration of the immersive virtual world have been realized by means of the stereoscopic visor Oculus Rift DKII.



a) b) c) d)

Figure 3 – The scenarios with the four installations: a) Small river; b) Big river; c) Small sea waves; d) Big sea waves. Upper figures show the point of view of the subjects. Lower figures show an external view of the position of subjects and of the installations.

2.3 Questionnaire

In order to evaluate the Restorativeness of the urban park and the environmental quality as perceived by subjects a Perceived Restorativeness Scale (PRS) and three additional questions about the global, auditory and visual quality of the environment were administered during the experiment.

The Perceived Restorativeness Scale (PRS), developed by Laumann [13] and based on studies on the Attention Restoration Theory (ART) [14], consists of 22 statements to which the subjects have to express the degree of agreement answering on a 7 points-scale defined numerically and verbally: Not at all (rating = 0); Very little (rating = 1); Pretty little (rating = 2); nor just nor (rating = 3); enough (rating = 4); Good (rating = 5) and completely (rating = 6).

The scale consisted of five components which affect the regenerative capacity of an environment (Restorativeness):

1) *Novelty*: capability of an environment to convey the feeling of being physically in a no ordinary place; 2) *Escape*: capability to transmit feelings of escape, from the psychological point of view, from routine and liability; 3) *Extension*: capability of an environment to move users in another physical or conceptual dimension; 4) *Fascination*: capability to attract involuntary attention. E.g. ability of a stimulus to hold attention without the individual needing to direct attention to focus upon the stimulus, or to inhibit other stimuli from gaining attention; 5) *Compatibility*: refers to a fit between the environment, the individual's inclination and the actions required by the environment.

Additionally three general questions about the global, auditory and visual feeling of the urban park were administered: 1) *From a global point of view, how would you rate the environment just explored?* 2) *From the auditory point of view, how would you rate the environment just explored?* 3) *From the visual point of view, how would you rate the environment just explored?*

To the previous questions the subjects have to express their opinion on the following 7-point Likert scale: (-3): extremely negative; (-2): very negative; (-1): slightly negative; (0): neither; (+1): slightly positive; (+2): very positive and (+3): extremely positive.

3. PROCEDURE

Seventeen subjects (7 female, 10 male) with mean age of 29,4 years (s.d.= 7.5) participated to the test. Before starting the test, to each participants were asked to fill out a sheet with their general information (gender, age, level of education, area of residence). Then, subjects were accompanied in the anechoic chamber. Once seated in the listening position (Fig.4) at the center of the anechoic room, they received instructions on the execution of the test. Then, participants wore the visor and they could start the exploration of the *control* scenario. Afterward, the experimental session started with the presentation of the first scenario. After about 15 seconds the PRS and the additional questions were administered through an additional audio playback system. The subjects could answer the PRS statements, verbally. To each subject the 5 scenarios described above were presented without any limits of time. The scenario sequence was balanced according to a Latin square.

Figure 4 – A subject during the experimental session.

4. RESULTS

To investigate how the combination of audio and visual characteristics of installations with water features can influence the Restorativeness, 5 different one way ANOVAs within subject were performed for each components of the PRS.

Results show significant differences among the scenarios for the components: *Novelty*, $F(4,64)=5.38$, $p<0.005$; *Escape*, $F(4,64)=4.16$, $p<0.005$; *Fascination*, $F(4,64)=14.88$, $p<0.005$ and *Compatibility*, $F(4,64)=4.86$, $p<0.005$.

As regards the *Novelty*, the mean comparison show that participants rated the scenarios with *big* installations ($M_{Big\_sea\_waves}=4.15$; $M_{Big\_river}=4.19$) better than those with small ones ($M_{Small\ sea\_waves}=3.78$; $M_{,Small\_river}=3.90$) and significantly different respect to the *control* scenario ($M_{Control}=3.30$, $p<0.05$). For the *Escape* component, mean comparison reveal that participants rated the different installations similar ($M_{Big\_waves}=3.71$; $M_{Big\_river}=3.65$; $M_{Small\_sea\_waves}=3.56$; $M_{Small\_river}=3.72$) whilst the lower rate was given to the *control* scenario ($M_{Control}=3.17$). As regards the *Fascination,* the mean comparison show that participants rated the installations similarly ($M_{Big\_sea\_waves}=4.27$; $M_{Big\_river}=4.53$; $M_{Small\_sea\_waves}=4.15$; $M_{Small\_river}=4.34$). All the installations were significantly different from the *control* scenario ($M_{Control}=3.38$). The mean comparison on *Compatibility,* show that participants rated the installation with big river ($M_{,big\_river}=4.22$) higher than those with small waves ($M_{Small\_sea\_waves}=4.05$) and small rivers $M_{Small\_river}=4.06$). Significant differences ($p<0.05$) were observed between the *big river* (M=4.22) scenario and those with *big sea waves* (M=3.82) and *control* ($M_{Control}=3.68$).

At the same time in order to investigate if the 5 scenarios were perceived differently in term of global, auditory and visual quality, 3 more one way ANOVAs within subjects were performed. Results only confirm that, in all the analyses, the *control* scenario was significantly different from those with the installations with water features. However, no other significant differences were observed. Mean comparison show the same trend for all the three questions.

5. CONCLUSIONS

This study examined the effect of the use of informational masking and of different audio-visual combinations for installations with water feature on the perceived quality and Restorativeness of a urban park.

The results confirm that the informational masking with water's sounds at levels 3 dB lower than the road-traffic background noise, provides a general enhancement of the subjective perception of the environmental quality of a urban parks.

Moreover, the presence of installations with water features improves their Restorativeness. In particular, considering individually each component of the regenerative capacity of an environment it can be observed that installations with big size which surround the observation position (such as the scenarios with the *big river* and *big sea waves*) enhance the positive feeling of the subjects to being physically in a no ordinary place. At the same time the mere presence of installations with water features has the general positive effect of improvement of the feeling of escaping and of fascination.

Further experiments should be performed in order to increase the sample of this experiment as well as enrich the variability of the scenarios with other installation with water features.

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