Design with Sound: The Relevance of Sound in VR as an Immersive Design Tool for Landscape Architecture

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Abstract: Sound in landscape architecture commonly focuses on noise. In design or planning process sound rarely plays a holistic and essential role. This is partly due to the need for more tools to address the complex topic. This research introduces novel opportunities to explore the importance of sound as an immersive design parameter in landscape architecture and planning within Virtual Reality (VR). The project investigates immersive sound experiences by presenting sonic data in audible form. A VR app was constructed from multiple on-location spatial sound recordings. Within a test case, the application was used by participants, comparing a conventional design approach with the proposed VR methodology. The outcome of the test clearly shows the importance of integrating sound in an audible form to enhance the comprehensive understanding of space. The paper will focus on the discussion of the technical as well as the design-specific components.

Keywords: Immersive soundscape, Virtual Reality, Landscape Architecture Design and Planning with Sound, Spatial Sound

1 Introduction

Sound profoundly influences our understanding and perception of space, its materials, and its environmental conditions. The same effect can also be seen in VR experiences. The field of virtual reality is increasingly focusing on sound design because the virtual environment's sounds immerse the user even more in virtual reality. A study by Jeon and Jo in 2020 examined how visual and audio information influences the satisfaction rate of the environment using VR. The visual and audio information distribution was 76% and 24%, respectively (JEON & JO 2020). Even though this study shows the overwhelming importance of the visual aspect of the landscape, aural experience has a noticeable part in the whole experience and understanding of a site.

Research on soundscapes in Landscape Design and Planning has been made but establishing a link between the conducted research and practice is still in its infancy. Nadine Schütz, who did her Ph.D. in landscape acoustics, noticed that even though sound is admitted to being part of a landscape, the unity of visual and aural perception in experiencing a landscape is not deeply a part of the practice of landscape architecture (SCHÜTZ 2017). The field commonly has a noise-oriented viewpoint towards sounds in the landscape, which is guided heavily by the known health aspects caused by noise. Today, the World Health Organization (WHO) names noise as one of the top environmental risks to health, pointing out that noise has auditory and non-auditory effects on people (WHO 2018). And according to studies, 20 – 40% of people are sensitive to noise (PESONEN 2005). Due to the given guidelines and laws on noise, planners have to use data that show estimated sound pressure levels (SPL) from noise emitting sources – noise maps.

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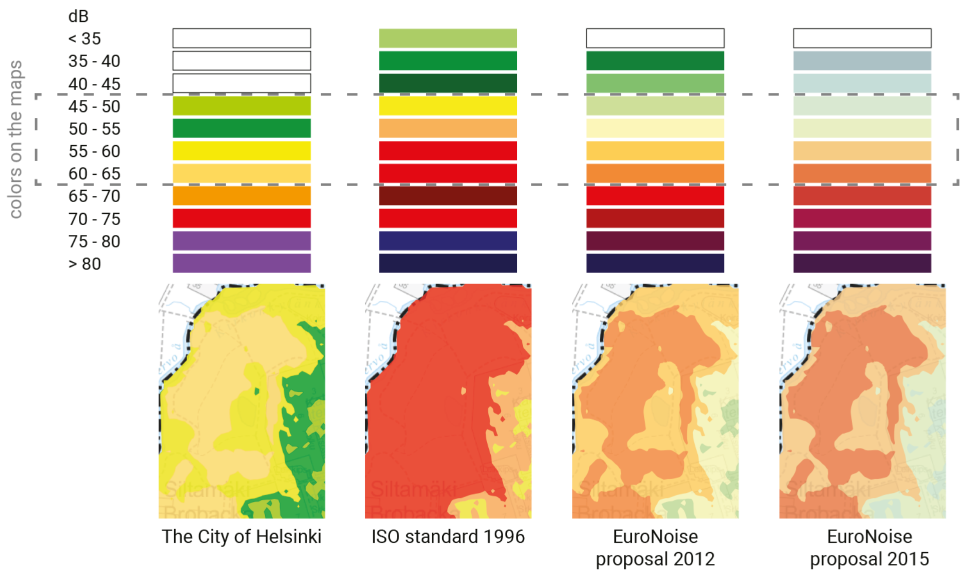

Fig. 1: Four different color schemes are compared with an example map. Only the ISO standard did not have the exact colors stated, e. g., in RGB. Colors for the ISO Standard were copied from Finland's Ministry of the Environment's report (EURASTO 2007).

Noise maps are an important way to show the estimated SPL of noise at a given location for planners and designers to follow the guidelines, laws, and restrictions concerning noise. But because noise maps are commonly the only source of information regarding sound that is available, planners and designers might use those maps for making broader interpretations of the quality of the site's sonic environment. However, noise maps are difficult to interpret as it requires in-depth knowledge of noise which landscape architects rarely have (RAIMBAULT & DUBOIS 2005). Non-experts thus rely almost solely on the colors used on noise maps for interpreting the data. We demonstrate the effectiveness of the used color scheme in Figure 1. From the left, the color schemes presented are: the scheme the city of Helsinki uses today (HELSINGIN KAUPUNKI 2019), ISO standard from 1996, European Acoustics Association's (EAA) proposals from 2012 (ALBERTS & ALFÉREZ 2012), and 2015 (WENINGER 2015). The city of Helsinki's version is roughly based on the ISO standard 1996 version – which is the case in many European countries. EAA proposed 2012 for a new standard, which was updated in 2015, among other things, to consider color vision deficiencies. The colors and the order of colors in the color scheme can affect how the data is interpreted.

Beate Weninger, who has studied the use of colors on noise maps, emphasizes the reasons why the color design of noise maps is essential by saying, "color is a physical stimulus that causes physiological as well as psychological reactions". Furthermore, she outlines, that if colors are not used properly, it can lead to data misinterpretation or even manipulation (WENINGER 2015). Because guidelines and laws are built on the SPL levels, in work-life for landscape planners, there is no high demand from, e. g., cities or municipalities to use soundscape information more holistically in designing or planning.

In addition to the problem of not having sonic data other than noise maps, the materials used and produced in the design and planning workflow are highly visual. Concentrating on visual presentations, planners and decision-makers are not encouraged to think about how the designs are perceived in real life with all senses (FRICKER 2019). Experiencing data in forms other than visual could result in different ways of designing, planning, and decision-making. Designing and planning for all senses could result in a healthier environment of higher quality, more usable, and safer for users. Jukka Jokiniemi studied the accessibility and cross-modality in the built environment. Jokiniemi reminds us that accessibility issues concern as well people with sensory impairment. By designing and planning a city to be perceived by all senses, the city becomes better for all (JOKINIEMI 2007).

This work proposes a workflow to create an immersive VR experience to store and perceive sound information. Secondly, we establish a test methodology for immersive sound experiences to draw hands-on conclusions on its implementation within a design workflow. The main research question addressed in this work is whether immersive sound experiences can support the design process by presenting sonic data in an audible form.

This work concentrates on existing soundscapes. Creating new soundscapes or modifying existing ones is outside the scope of this work. The immersive sound experience is not meant to work as a tool for designing or planning per se but as a medium that helps integrate sonic data into the design or planning process. Planning tools usually have a slow implementation rate (DAVIES et al. 2009), which guided the scope of the work to concentrate on the implementation of sonic data in the planning process.

The overall goal of the work is to establish a workflow of sound integration in VR, which can be applied to other planning and design tasks. The work supports the field of landscape architecture in the practical implementation of sound as relevant data for design and planning.

2 Case Study – Sonic VR App Design

2.1 The VR App

A VR experience is created to provide the planner with audible sonic data collected from the site. The VR experience consists of a test site on which the user can visit 59 locations, the points where the soundscape of the site was recorded. The construction pieces of the VR app are shown in Figure 2, which we introduce in this chapter.

The chosen test site is located in Helsinki due to using Helsinki's existing 3D model as the visual data. The requirements for selecting the site were the size of the area and providing sufficient free and unprogrammed space. The noise map from the site shows some variation, and the site should not be well-known to most participants in the design test to ensure a similar starting point between the participants.

The audio data is in ambisonic format and collected by a virtual reality audio recorder (Zoom H3-VR). The recordings were recorded for two days (weekdays in the daytime) with similar wind conditions. The order in which the recordings were taken was randomized. The SPL level (LAeq) was measured at the same time as the recording, to calibrate the recordings afterward, because the gain level of the recorder needed to be changed between the recording events.

The audio files are in wav (Waveform Audio File) format and have four channels. According to Ortolani, ambisonics is a 3D audio technique that enables sounds to be heard from any direction – compared to stereo or surround sound techniques, where the listener can localize the sound sources only on a 2D plane (ORTOLANI 2015). Before using the ambisonic recordings in a VR experience, a binaural decoder needs to turn ambisonics into headphone signals. Decoding the files for headphones usually uses a small set of so-called virtual loudspeakers" (ZOTTER & FRANK 2019). This allows connecting the spatial sound to the head-tracking abilities of the VR headset, leading to the user's ability to localize sound sources in the VR experience, linking the visual and aural landscapes.

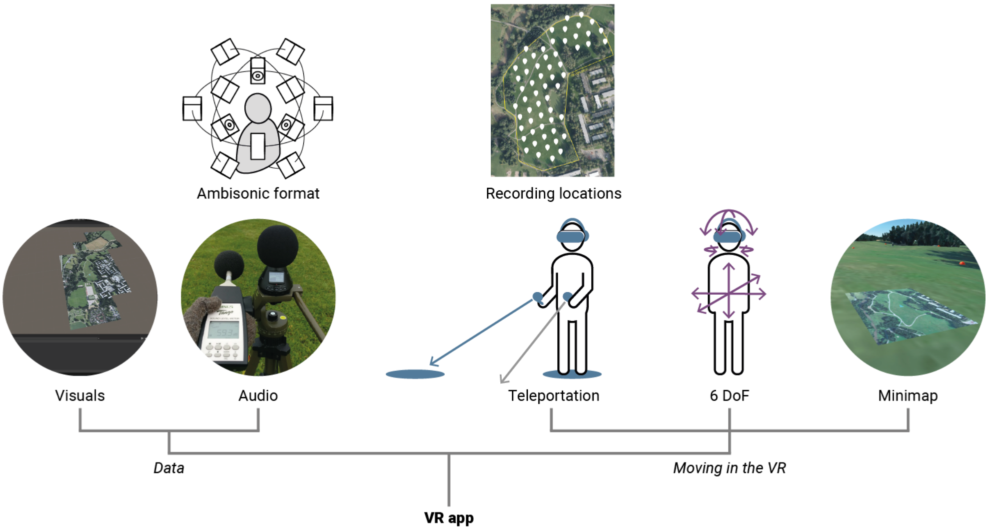

Fig. 2: Components of the generated VR app, separated into data input sources and user functionalities in relation to design and planning applications

The user moves in the VR experience using teleportation as the virtual locomotion technique, which enables the user to move instantly to a new location. At the given locations, the user can move around freely – due to the used six degrees of freedom (6 DoF). They refer to the position and rotation along the three world axes, x, y, and z. According to Lang, these six degrees of freedom can express any movement (LANG 2013). For more straightforward navigation at the virtual site, a mini-map was displayed in the VR. The map remains at the user's side and shows where they are.

2.2 Design Test

The immersive VR experience as a tool in design workflow was evaluated with a design test. The 21 participants were graduates or students in the planning fields. The design task was to identify a suitable location for a small-scale structure within the park perimeters. The emphasis on sound in the study was carefully hidden from the participants before the test. In the advertisement for the test only the use of VR was stated. The idea of the design test was to see how the given data influences the results of the design task. The participants were split into two focus groups. The VR experience supplied to one focus group was visual only, whereas it was audio-visual for the second focus group.

In the design task assignment, the structure (such as a gazebo or a pergola) was described to be for informal meetings and small gatherings. Stating the activity for the structure is essential because it gives a point of view for the task. It is also crucial for evaluating the soundscape. Studies have shown that the listener's activity or intention for an activity influences the assessment of the appropriateness of a soundscape (NIELBO, STEELE & GUASTAVINO 2013).

The materials for the participants in the design test included basic information about the site in the form of maps, text, and pictures. In addition, participants had a 3D model of the site and the VR experience. The 3D model was the 3D view of Google Maps, which participants accessed through a laptop.

The design test had the following steps. First, the participants filled out a short background information questionnaire. Then they had time to familiarize themselves with the site's materials, including the VR experience, after which they gave their answer – the structure's location. Next, the participants assessed the supportiveness of the provided materials, and a semi-structured interview was completed.

2.3 Evaluation

Twenty-one participants took part in the design test, divided into the focus groups with (11) and without (10) sound in VR. The participants were all landscape architects, and according to the results of the background questionnaire, the different attributes (e. g., level of studies, work experience) were relatively evenly distributed to the two focus groups.

The answers – the locations participants gave for the new structure – were distributed over the designated design area. In a few areas, there are clusters of answers; see Figure 3. In Figure 4, the answers are presented over the noise map, color-coded into the two focus groups, and divided into four clusters. Inside the area marked as "1" are answers from almost half of the participants, i. e., 9 out of 21. According to the noise map, they placed the structure on the north side of the pond, which has the quietest spot in the park. Of these nine answers, six came from the focus group that did not have sound in the VR. Their knowledge of sound leaned only on the noise map. Inside area "2" are three answers from the focus group with no sound in VR. These are closer to the road on the river's west side. The road is the primary source of noise in the park. Inside area "3" are five answers from the focus group that had sound in VR. Of these five answers, three were almost in the exact location, on the south side of the pond. This location is marked with yellow on the noise map, which is quieter than most of the park. Inside the area "4" are four answers, of which three are from the focus group with sound in the VR.

After the design task, the participants assessed the given materials on a scale of 0 (not at all) to 5 (immensely) on their supportiveness for the design task. There were slight differences in which materials the focus groups found most supportive. The group with audio in their VR experience assessed the VR experience very highly, followed by the 3D model. The other group saw the map showing contour lines as the most supportive, followed by the VR experience. They assessed the 3D model as relatively low. Noise map as a material was evaluated in both groups evenly, grading around 3,3. The difference between the groups is that the group without sound in the VR considered a few more materials as more supportive than the noise map.

Fig. 3: Location of design test answers assembled on the map

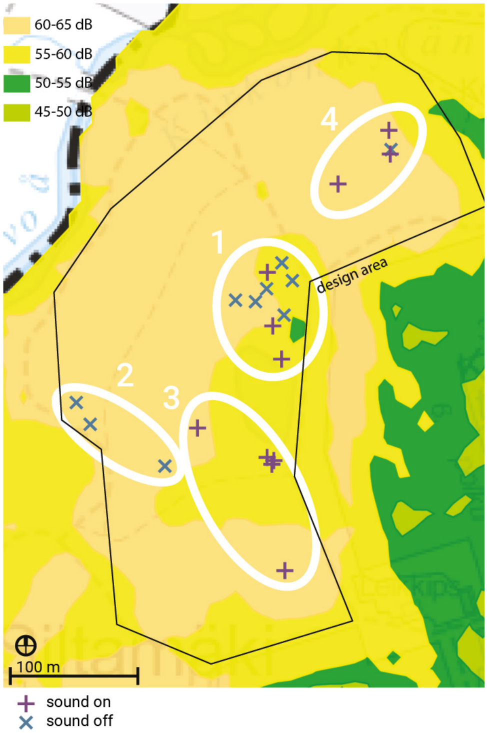

Fig. 4: Location of design answers by focus groups assembled on the noise map

Finally, a semi-structured interview was conducted. VR as a medium was a positive encounter for the majority. The participants with audio in the VR brought up that VR could help planners understand sound pressure levels. The teleportation in the VR experience causes the effect of hearing the differentiation of the SPL of different locations due to the sudden change of audio file when teleporting. When discussing the use of sound in the field, the majority of the participants were surprised by how little they knew about sound, although they think that sound is a significant part of the environment. Sound had not been an evident part of their studies in the field, and concerning work-life, a majority had worked with sound, but commonly it was from the viewpoint of noise. In general, the use of sound has not had a noticeable part in the participants' professional works. Using data on audio in an audible form in design or planning was rare among the participants. Discussing noise maps, it became clear that decibel levels are pretty abstract to many participants. A few participants brought up directly that they do not understand what the decibel levels in the noise map mean. Participants concentrated more on the noise map's colors than the numeric decibel values.

3 Discussion and Outlook

As expected, there were some differences in the answers between the two focus groups in the design test. The group with audio in the VR experience avoided noisier areas more, and they were able to find other suitable locations for the structure. The noise map guided the decision-making more for the group without audio in the VR experience, giving limited choices regarding acoustic comfort on the design test site. Based on the self-assessment and the interviews, the audio in VR was an essential source of information for the design task. This shows that the VR experience with audio did not exclude the information the noise map gave – it supported it (FRICKER 2018).

Having sound materials in an audible form brings a broader variety of aspects from sound into consideration, contrary to noise maps. The presented immersive sound experience with a design task showed that it has the potential to support planners in the design process by bringing the soundscape as an intuitively accessible resource.

In the interviews, some participants brought up their need for knowledge for interpreting the data on noise maps, which supports the literature stating that planners do not often have the expertise to interpret noise maps. Planners rely on interpreting the noise map's colors to analyze their data. The group's answers in the design task without audio in VR also seem to support this claim. Many participants concentrated on the small, darker green area, which might have gotten too much attention because the color scheme Helsinki uses in its noise maps does not have an intuitive order of colors. As mentioned above, the focus group without audio in VR had answered near the quietest spot (marked with green color) on the site more than the other group. Their only information about the soundscape came from the noise map, which guided their answers. In contrast, the group with audio in VR could find other suitable locations, seen in the small clusters of their answers. The interviews showed the depth in which planners consider sound in design and planning. Design and planning with sound lean heavily on noise maps and guidelines relating to decibel levels, which planners need help interpreting. The sound layer in the landscape should be taken into deeper consideration. The main results of the discussion are:

1) VR has the potential as a medium for storing and perceiving soundscape data so that it can be linked to the visual landscape.

2) Making the noise maps easier to understand for non-experts would benefit planners and the public. The noise map's color schemes could be changed to a more understandable and accessible version, as discussed in the introduction of this paper.

3) The built environment could become more pleasant and usable by planners actively listening to the environment and bringing that data into design and planning. In addition, valuable sound environments could be identified, preserved, and created more extensively, and environments could improve for the visually impaired.

In conclusion, the conducted research highlights the impact and importance to further develop the use of VR in landscape architecture from the perspective of sound. As a result, it will support us to design and plan our environments with more "open ears".

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