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COMPARISON OF SOUNDSCAPE ASSESSMENT RESUTS ON-SITE AND IN THE LABORATORY

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ABSTRACT

The soundscape approach aims to design pleasant acoustic environments. It is a comprehensive assessment that uses field questionnaires, interviews, and measurements. However, field studies do not always allow for a full evaluation. Virtual environments have great potential for experiencing various urban scenarios and carrying out soundscape studies. In this study, it is aimed at making an evaluation of the transfer of the soundscape questionnaire to the virtual environment. The ISO/TS 12913-2 standard has questions and definitions for the preparation and evaluation of surveys in soundscape studies. This study evaluated the affective quality attribute pairs defined by this standard in virtual and real environments. Within the scope of the study, binaural audio and HD video recordings and a questionnaire were carried out in two different urban areas. After that, the videos and sound recordings taken were re-prepared for the Multimodal Measurement Laboratory (MMM) at the Dresden University of Technology. The field questionnaire conducted in the two urban areas was repeated with participant groups in the laboratory environment. As a result of the study, it was seen that there was no significant difference in the participants' evaluations of affective quality and that the practices in the fields and in the MMM were consistent.

Keywords: *virtual reality, soundscape assessment, multimodal measurement laboratory*

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1. INTRODUCTION

Contemporary urban areas are plagued by a multitude of issues that have a direct impact on our standard of living and impede the creation of pleasant environments. Environmental noise is a significant challenge faced by urban areas. It is an important public health concern and ranks among the foremost environmental hazards to human health [1]. Research concerning environmental noise is geared towards enhancing the standard of urban living and augmenting the quantity of acoustically pleasant urban areas. There is a need to investigate more systematic design strategies for the soundscape that can be sustainable and integrated into long-term planning for the future of urban areas.

In soundscape studies, user perception is extensively investigated. The field of soundscape studies is concerned with the design of pleasing acoustic environments for individuals. This approach deals with elements such as people, context, and sound sources together. It encompasses a range of disciplines and methodologies aimed at comprehending the ways in which individuals perceive and interact with the acoustic environment. The role of user perception is significant in the soundscape approach. The endeavor to ascertain the perceived emotional quality involves conducting interviews with individuals and administering survey studies.

In recent years, technology has facilitated the conduct of comprehensive research, enabling the identification of pertinent findings and informed decision-making. It is important to carry out these studies and test the decisions made beforehand, especially in urban areas where the decisions have costly and long-term effects. Virtual reality technologies are of great importance in solving existing problems in cities or finding solutions to potential problems. Virtual reality technology is utilized to visualize potential outcomes resulting from urban decision-making processes.

In these virtual reality environments, different approaches are being tried, and studies focusing on user perceptions are being conducted. With these studies, citizens' perceptions of urban problems as well as their satisfaction or discomfort levels can be determined. With the development of technology, it is possible to use many data points about the city in real time and to make virtual vitalizations in the light of real data [2]. Virtual reality is used in the design of important areas such as highways [3], urban green spaces [4], and historical areas [5]. These studies, in which user perception can be actively used, contribute to making cities smarter, more environmentally friendly, and more sustainable. And virtual reality technology is utilized to circumvent uncontrollable factors such as weather or unrelated urban interactions. Due to these factors, it is highly appropriate for implementation in the field of soundscape research.

In soundscape studies, field surveys have an important role in evaluating the acoustic environment. In ISO/TS 12913-2, there are standard questions and definitions for survey preparation and evaluation. The suitability of the questions and methods in this standard in a virtual environment has not been fully tested. Maffei et al. previously conducted a comparative study wherein the perception of people exposed to virtual reality technology was compared to that of those exposed to a real situation. And they have seen that immersive virtual reality gives results compatible with the real environment [6]. However, this study was conducted in a limited area. For this reason, it should be tested with different virtual reality possibilities in environments with different acoustic characteristics. The replication of places with diverse acoustic properties in a virtual environment can enhance the creation of virtual environments that closely resemble physical environments.

In this study, it is planned to use these advantages provided by virtual reality technology to prioritize user perception and use the soundscape approach. The objective of this study is to assess the validity of soundscape questionnaire research in a virtual environment. The study encompassed the collection of audio and video recordings in the field as well as the administration of questionnaires in two distinct urban regions. Subsequently, the audiovisual materials were prepared for virtual environment testing in the Multimodal Measurement Laboratory (MMM) at the Dresden University of Technology.

The questionnaire administered in two urban areas was replicated among participant groups in a laboratory setting. The study assessed the transfer of areas with varying acoustic characteristics to the virtual environment, taking into account human perception.

2. MATERIAL AND METHOD

The purpose of this study was to test the validity of field surveys undertaken in soundscape investigations in the virtual environment. Because of this, the study compared surveys conducted in the field and in a virtual environment. The scheme of workflow is shown in Figure 1.

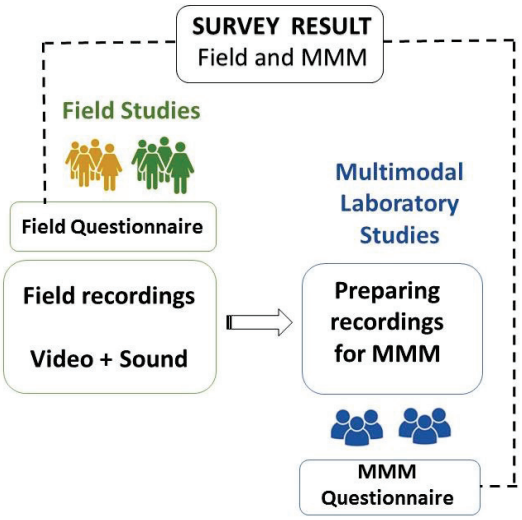

Figure 1. Scheme of the workflow.

In the study, questionnaires and recordings were made in the field areas. Afterwards, these records were prepared for the multimodal laboratory (MMM). And the same questionnaire was applied to the participants in the MMM for these two areas.

The survey used in the study consists of four questions. It was prepared in accordance with the questions specified in the TS/ISO 12913-2 standard [7]. The first question dealt with sound source identification. Sound sources are classified as traffic noise, other noise, human sounds, and natural sounds, and a 5-point scale is provided for users to choose from. The second and third questions are about how people describe their current sound environment. The last question is about perceived affective quality. This question received eight adjective pairs and a 5-point scale. The participant rated how much they agreed or disagreed with each adjective's description of the acoustic environment. Within the scope of the study, the perceived affective quality was compared.

In the study's continuation, specified fields and field studies are explained first. Afterwards, the preparation of the audio and video recordings taken in the field for use in the virtual environment was explained.

2.1 Field Study

This study involved the collection of audio and video recordings from two distinct locations situated in the central region of Dresden, Germany. The locations exhibit different characteristics: the first site is an intersection with significant vehicular flows, and the second is a natural park area.

Figure 2.Central Station Dresden.

The first study area is the central station. The central station is an intersection area where bus, train, tram, vehicle, and pedestrian traffic intersect. The field area is shown in Figure 2. Audio and video recordings were captured from a location that provided a view of the station building and the adjacent road, in an area where traffic noise is the predominant acoustic feature. The survey was carried out within the visual boundaries of the video recording. The A-weighted equivalent continuous sound pressure level (L_{Aeq}) in the 3-minute video created for MMM is 69.8 dB(A).

Figure 3.Großer Garden, Dresden.

The second study area is Großer Garden. Today, it is the largest park in the city center of Dresden. It has a nearly rectangular plan on an area of approximately 1.8 square kilometers. Figure 3 depicts the location where audio and video recordings were captured in the research. The survey study was limited to the small lake area where the records were taken. The A-weighted equivalent continuous sound pressure level (LAeq) in the 3-minute video created for MMM is 56.8 dB(A).

2.2 Preparing the scenes for MMM

The present investigation was carried out at the Multimodal Measurement Laboratory (MMM), which integrates virtual reality (VR) apparatus for various modalities and has the capacity to deliver advanced, interactive simulations [8]. The laboratory conducted preparations of audio and video recordings for a virtual environment, featuring 500 speakers and room acoustics that were designed in accordance with DIN 15996. Visual processing is done in full HD on an acoustically transparent screen.

To prepare the audio and video recordings for MMM, approximately 10 minutes of recordings from all locations. The videos were converted into three-minute HD videos. Since it is thought that people can experience the environment by sitting in the laboratory, the video recording was taken from a height of 1-30 cm above the ground. Omnidirectional and binaural audio recordings were made with SQuadriga II. Binaural recordings were used in the laboratory. The IOSONO Spatial Audio Workstation (SAW) is used in the lab, which enables the editing of complex sound scenes. Video and audio arrangements and synchronization are done in Nuendo4 software. The binaural recordings are placed at the level of the left and right ears of the participant sitting in the laboratory. It is done with the help of the schematic plan in the interface of the Nuendo4 software.

Two distinct time periods were utilized to conduct the surveys at MMM. Initially, the surveys pertaining to the central station were carried out, followed by those related to the natural park. The MMM experiments share common participants. However, it was noted that the individuals who participate in the MMM surveys are not necessarily identical across all surveys.

The participant in MMM surveys initially sits in the lab and interacts with the environment displayed on the screen in front of them. After the 3-minute video, the participant fills out the survey form.

3. EVALUTION OF THE RESULT

The evaluation of the survey results dealt with two different study areas separately. The study aimed to compare the perceived affective quality within its scope.

3.1 Central Station

For the area in front of the central station selected for the study, data from the field and MMM survey respondents is organized in Table 1.

Table 1. Information on survey participants.

Survey Location	Number of participants	Age range
Central Station	15*(8Male, 7Female)*	22-45*(M=35, SD=8.87)*
MMM	15 *(11Male, 4Female)*	25-36 *(M=31.13, SD=3.44)*

The questionnaire was prepared in English and German. Participants were offered the questionnaire in their preferred language. Participation in the survey conducted in the field area was low. The low attendance at the survey can be attributed to the intersection's location and proximity to a high-traffic area. After that, the same number of participants were selected for the survey conducted at MMM.
In this study, a comparison was made between the adjective pairs that were used to describe the affective quality of the real and virtual environments that participants experienced. Participants were given eight pairs of adjectives and a 5-point scale (1-strongly disagree, 5-strongly agree), and it is asked to what extent you agree or disagree with that description of the sound environment. The averages of the responses of the two groups are shown in Figure 4.

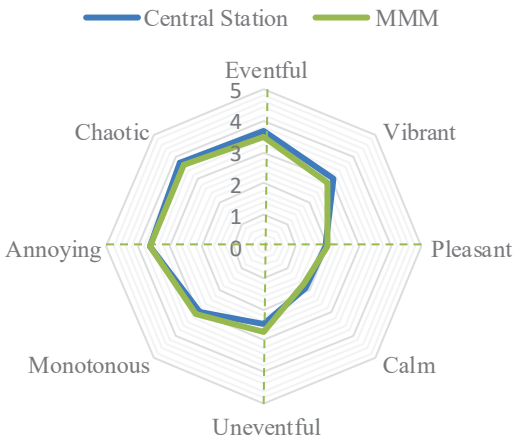

Figure 4. Field and MMM survey results to auditory affective quality.

The responses of the participants to the same pairs of adjectives are shown separately. The spread of responses given from darker to lighter shades are shown in Figure 5. CS indicates responses at the central station and MM indicates laboratory responses.

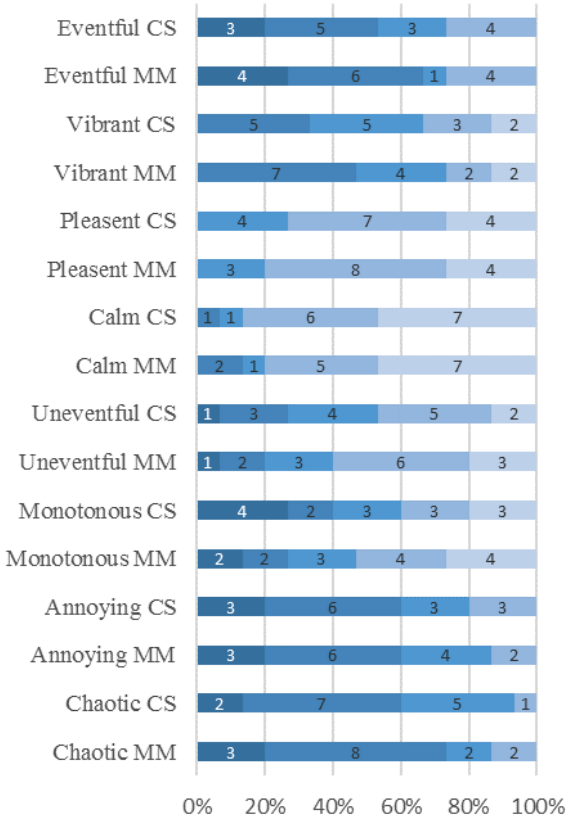

Figure 5. The lightest blue represents 1 - strongly disagree, the darkest blue represents 5 - strongly agree and the number of participants is shown above the colors.

Based on the obtained outcomes, it was observed that the individuals perceived the two settings as chaotic, eventful, and annoying. Moreover, both regions are not perceived as pleasant and calm.
In central station, the pleasantness value as defined in ISO/TS 12913-3 was found to be p = -3.00 and the eventfulness value as e = 2.66. According to the results of the survey conducted at MMM for the same area, the pleasantness value was found to be p = -3.16 and the eventfulness value as e = 2.04. According to the assessment of these characteristics in ISO/TS 12913-3, an eventful environment is one that is full of human

activity, such as a city center [9]. This area is also in the center of the city and is an intersection area. It shows that the place is perceived as chaotic and a combination of annoying and eventful in both areas.
A correlation analysis was carried out to evaluate the effects of real and MMM experience on affective quality adjectives in order to find out if there were any significant differences between both survey settings. Table 2 shows the mean values, p-values, and Spearman's rank correlation. The mean values of the attributes M_1 represent the result of the Central Station field survey, and M_2 represent the result of the Central Station MMM survey.

Table 2. P-values for each pair of attributes and their average values in both fields.

Pleasant	**Vibrant**	**Eventful**	**Chaotic**
M_1=1.93 $M_{2=}$ 2.0 *rs =942* *p =.000*	M_1=3.06 $M_{2=}$ 2.86 *rs=900* *p =.000*	M_1=3.66 $M_{2=}$ 3.46 *rs=931* *p =.000*	M_1=3.80 $M_{2=}$ 3.66 *rs=837* *p =.000*
Annoying	**Monotonous**	**Uneventful**	**Calm**
M_1=3.66 $M_{2=}$ 3.66 *rs=976* *p =.000*	M_1=2.93 $M_{2=}$ 3.0 *rs=865* *p =.000*	M_1=2.46 $M_{2=}$ 2.73 *rs=913* *p =.000*	M_1=1.86 $M_{2=}$ 1.73 *rs=983* *p =.000*

The p-values for all the Central Station and the MMM surveys were *p<.000.* Additionally, all Spearman correlation coefficients were *rs >800*, demonstrating the high degree of consistency between all of the values. The findings show that there are no differences between the attitudes assessed in the survey studies carried out in the field and in the MMM.

3.2 Großer Garden

For the area Großer Garden which is selected for the study, data from the field and MMM survey respondents is organized in Table 3.

Table 3. Information on survey participants.

Survey Location	**Number of participants**	**Age range**
Großer Garden	*22(9Male, 11Female)*	22-65*(M=37.75 SD=13.85)*
MMM	24 *(18Male, 6Female)*	20-37*(M=29.87, SD=4.58)*

The questionnaire was also prepared in English and German. It was made available to participants in their chosen language. In the field survey, it was easier to communicate with survey participants than at the central station. As parks are public spaces for people of all ages, the age range of participants is wider. On the other hand, mostly researchers and students participated in the survey of the same field records in MMM. Therefore, the age range, mean value, and standard deviation are quite different in the two survey groups.
The question about affective quality was repeated in these fields with the same adjective pairs. The averages of the responses of the two groups are shown in Figure 6.

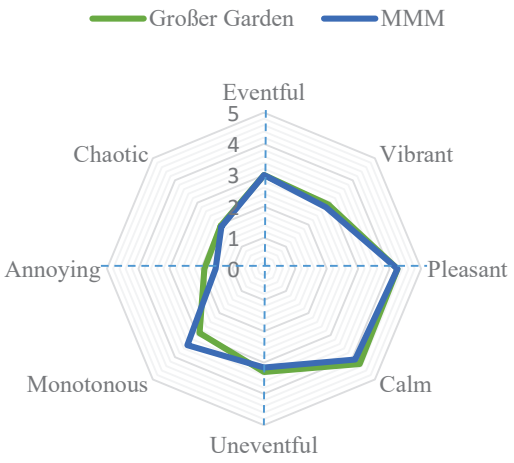

Figure 6. Field and MMM survey results to auditory affective quality.

Based on the obtained outcomes, it was observed that the individuals perceived the two settings as pleasant and calm. It can be assumed that an uneventful environment without activity would typically be characterized by a lack of human presence. However, according to the survey conducted in the natural park lot, individuals were observed engaging in activities such as resting and participating in sports. Because of the presence of people in the area, it could hardly be described as uneventful. The area also includes some bird footage, including that of ducks and other waterfowl.

Based on the average findings in Figure 6, it can be observed that the sole variable that exhibits a higher value in the MMM surveys is monotonous. Although it does not cause a significant difference between the results, it is expected that the participants do not feel like natural environments in the evaluation of green spaces in the virtual environment.
The spread of responses from darker to lighter shades is shown in Figure 7. GG indicates responses at the Großer Garden, and MM indicates laboratory responses.

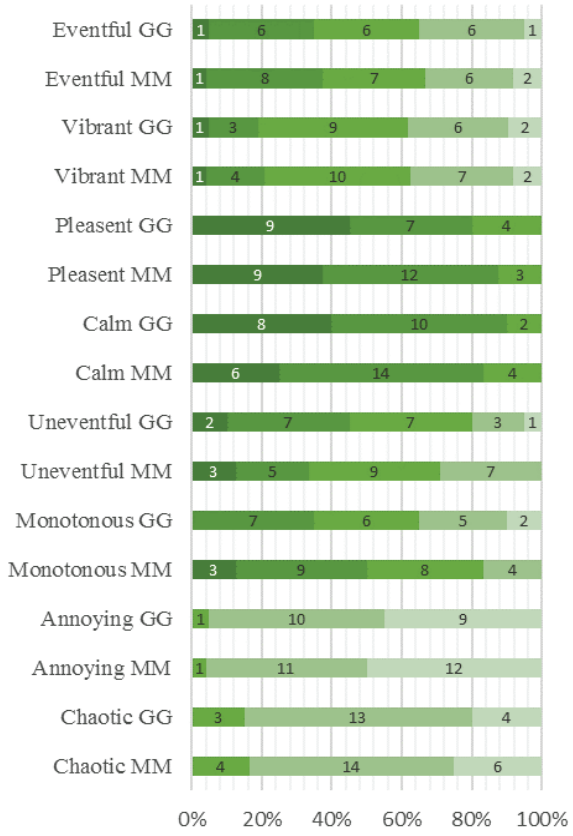

Figure 7. The lightest green represents 1 - strongly disagree, the darkest green represents 5 - strongly agree and the number of participants is shown above the colors.

In Großer Garden, the pleasantness value as defined in ISO/ TS 12913-3 was found to be p = 4.01 and the eventfulness value was e = -1.96. According to the results of the survey conducted at MMM for the same area, the pleasantness value was found to be p = 3.79 and the eventfulness value was e = -2.17. It shows that the place is perceived as calm and a combination of pleasant and uneventful.

A correlation analysis was also conducted for this field study. Table 4 shows the mean values, p-values, and Spearman's rank correlation. The mean values of the attributes M_3 represent the result of the Großer Garden field survey, and M_4 represent the result of the Großer Garden MMM survey.

Table 4. P-values for each pair of attributes and their average values in both fields.

Pleasant	**Vibrant**	**Eventful**	**Chaotic**
M_3=4.25 $M_{4=}$4.25 *rs=930* *p =.000*	M_3=2.9 $M_{4=}$2.79 *rs=884* *p =.000*	M_3=3.00 $M_{4=}$3.00 *rs=890* *p =.000*	M_3=1.95 $M_{4=}$1.91 *rs=798* *p =.000*
Annoying	**Monotonous**	**Uneventful**	**Calm**
M_3=1.90 $M_{4=}$1.54 *rs=917* *p =.000*	M_3=2.90 $M_{4=}$3.45 *rs=862* *p =.000*	M_3=3.30 $M_{4=}$3.16 *rs=922* *p =.000*	M_3=4.30 $M_{4=}$4.10 *rs=756* *p =.000*

For Großer Garden, the p-values were $p<.000$. And all Spearman correlation coefficients were $rs > 700$, demonstrating the high degree of consistency between all of the values. The results demonstrate that there are no variations between the attitudes evaluated in field survey studies and in the MMM.

4. CONCLUSION

The affective quality attribute pairs considered are an important component of soundscape research. The study therefore compared the performance of the standard soundscape questionnaire in virtual and real environments. And for this evaluation, two areas with different acoustic characteristics were considered. The results of the study administered in the fields and in the MMM were found to be consistent with each other. There is no significant difference in the participants' evaluation of adjective pairs. This conclusion, which may make it possible for soundscape studies to be carried out in a virtual environment, needs to be backed up by additional research that needs to be carried out. It should be enhanced with locations that have different acoustic characteristics. It is important to recognize that the survey was conducted in a limited geographical area with a limited sample size. It is suggested that research endeavors increase the number of comparable investigations and expand the scope of their inquiry in order to better inform future projects.

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