SOUNDSCAPE EVALUATIONS OF MUSIKIOSK: A MIXED-METHODS IMPACT STUDY OF A MUSICAL INSTALLATION IN AN URBAN PARK

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The opportunity to purposefully add sounds to the urban environment with the intention of improving quality of life is rare - more so, the opportunity to empirically study those effects. We introduce Musikiosk, an interactive music installation and environmental monitoring station, as an exploratory project with these goals. A comprehensive mixed-methods research project, using an approach called soundscapes, accompanies the installation to try and capture measurable immediate and longitudinal impacts, positive and negative, of Musikiosk on the community. Environmental monitoring via a microphone input will provide information about system usage, physical measurements of the acoustic environment, and playback levels. Findings will contribute toward theories on the roles of activity and music in soundscape evaluations and will be among the firsts to observe changes in a manipulated soundscape. Parties that stand to benefit are park users, residents, researchers, and the city for various reasons.

INTRODUCTION

The opportunity to purposefully add sounds to the urban environment with the intention of improving quality of life is rare - more so, the opportunity to empirically study those effects. We introduce Musikiosk, an interactive music installation and environmental monitoring station, as an exploratory project with these goals. We aim to develop and validate evaluation methods to best integrate the users' various perspectives at different points in the project's timeline. Musikiosk is planned for installation in the gazebo of an urban park in Montreal in the mid-Summer of 2015 in a collaborative effort between CIRMMT, ÉTS, McGill and the city of Montreal. In brief, Musikiosk allows people to bring their own sounds into the public realm by providing an open connection to an outdoor speaker system free to the public. Environmental monitoring via a microphone input will provide information about system usage, physical measurements of the acoustic environment, and calculations of appropriate sound playback levels for the device. A comprehensive mixed-methods research project, using an approach called soundscapes, accompanies the installation to try and capture measurable impacts, positive and negative, of Musikiosk on the community.

1 PREVIOUS WORK AND RESEARCH QUESTIONS

1.1 Previous work

A number of previous studies consider outdoor sound installations that modify the sounds of urban spaces like city squares and parks, using various types of added sounds, for example, artificial [1] and pre-recorded (prepared compositions, for example, to complement fountain noise [2] sounds. Another study took the approach of creating artificial sonic environments in parks that "intelligently" added sounds to reduce annoyance, but it was done in the context of noise pollution management, rather than attempting to create positive environments [3]. In that study, the installation created a masking sound in real-time to reduce the annoyance created from noise due to a highway. Lastly, in a study on auditory comfort in public spaces [4], the authors showed that sound source type played a role in evaluations of comfort; introducing sounds to spaces that were considered pleasant, even rather loud ones, produced a considerable improvement in acoustic comfort.

1.2 Musikiosk and why it's different

The core of the Musikiosk technology is a public-facing audio input that allows users to connect their own wired or wireless musical device, like an mp3 player or musical instrument, and play it through a provided, relatively high-quality outdoor sound system. Rather than enabling loud, extroverted public performance, Musikiosk offers good quality sound for smaller, intimate gatherings in a public setting, such as: rehearsing a small ensemble needing amplification, sharing music with friends, spontaneous dancing, or holding a yoga class. We use microphone inputs for ambient noise monitoring and level adjustments and to enable recording of live performances. Musikiosk will offer a number of modes: daily, where users can turn levels down but not up; special, i.e. louder for approved events; and off, for nighttime and during the presence of other activities that may conflict, chosen on a case-by-case basis. The associated research, which includes physical measurements as well as evaluations from participants, will provide information about ways in which to update the system based on user feedback or as problems arise.

1.2.1 Monitoring with acoustic indicators

A microphone placed a certain distance from Musikiosk will collect a number of acoustic indicators over the course of the project. Brocolini et al. [5] provide a review of acoustic indicators for urban soundscape, including indicators of energy (e.g. L_{eq}, L_{A5}, L_{A10}, L_{A50}, L_{A90}, Traffic Noise Index) and indicators of events ($NNE_{L>Lx}$ and $MI_{L>Lx}$). Our monitoring system will capture and store A- and C-weighted L_{eq} and ⅓-octave bands. In the adjustment phase of Musikiosk (described in Section 3), we will also manually collect longer recordings of the acoustic environment to determine which indicators best match human judgments in this specific context and incorporate them into the full implementation of the Musikiosk software. We will also consider indicators that have been used for musical sounds specifically, such as loudness, roughness, and sharpness. Though there are a large number of acoustic indicators, many are derived as a way to measure the negative impacts of noise rather than account for human perception. Thus, these indicators don't fully capture the type of evaluations that a Musikiosk user or residents might make about the system.

1.2.2 Musikiosk as soundscape research

From this project has emerged the need to measure the impact of an interactive music installation beyond acoustic indicators, necessitating an interdisciplinary approach that captures the positive benefits and not just a lack of problems. Interventions in the soundscape have a broader impact on the community (residents, park users, nearby business). Soundscape is defined as the acoustic environment as perceived and understood and/or experienced, by people or society, in context [6]. Central to soundscape research is the methodological shift from solely quantitative approaches (noise control) to more holistic approaches related to human perception in relation to social activities, as soundscapes cannot be assessed exhaustively in terms of acoustic measurements. Prior research has shown that soundscapes contribute to a sense of place and quality of life, carry information about the types of actions people may perform in the environment, and are evaluated as a function of envisioned activities [7][8][9]. Calls have been made for mixed-methods approaches to evaluate the quality of acoustic environments, especially with in using participant-centered methods that capture attention, knowledge, experience, and context [10]. Specifically, regarding the soundscape quality of outdoor urban areas, one study tested the suitability of various acoustic indicators for their power in predicting human soundscape evaluations [11]. While between 25 and 30% of variance in the soundscape quality was predicted by various equivalent sound level measurements (L_{Aeq}, L_{A50}), the study revealed a need for the development of event-based indicators (as in [5]) for sounds like nature sounds and technological sounds, due to the variance those had on the participants' evaluations of the soundscapes measured.

1.3 Research Questions

Our research questions, which follow the structure of the remainder of the document, are as follows:

- What are the appropriate development considerations for a technology like Musikiosk?
- How does one best integrate public input into the design and evaluation of an outdoor music installation? And what performance rules must be implemented to reduce negative impacts of a Musikiosk?
- What are the appropriate methodologies for evaluating a musical soundscape intervention?

2 TECHNOLOGIES

2.1 Overview and Requirements

The research team articulated the following requirements for the Musikiosk system, expanded in Section 2.3:

- a small and compact device with secure components that can be left in a public space for long periods of time;
- an acoustic monitoring system for calculating acoustic indicators and taking audio recordings;
- automatic and autonomous operation and sound level control, including different modes for various operating conditions;

- wired and wireless access (for users to stream their music, for maintenance and remote monitoring and data access);

To frame these concerns more generally, it is important to understand that the Musikiosk will be installed in a busy urban space with a light residential context. As the device is intended for a general, rather than tech-savvy audience, Musikiosk offers connection both via Bluetooth and a 1/8th-inch stereo audio jack. To best understand and meet the needs of the community, the playback system is controlled by an acoustic monitoring technology during the day and turned-off at night. Overall sound levels of the playback system are dynamically controlled based on measurements from an external microphone located close to the sound system that will ensure Musikiosk is not playing sounds too loudly. In addition to the real-time sound level control, a calendar feature schedules sound level limits and equalization settings depending on the time-of-day, the day of the week, and the type of activities scheduled. While most of the time, Musikiosk operates in the default, public mode, an "authorized" event mode allows pre-approved artists to access higher sound levels and also a custom equalizer

2.2 Hardware Overview

In line with the global project goals for flexibility, customizability, and affordability, open-source technologies were used. While other projects, such as the EAR-it **Error! Reference source not found.** and Citygram [12] used the BeagleBone Black board and an Android Mini PC, respectively, for acoustic sensing, Musikiosk uses Raspberry Pi (Rpi) because of available add-on sound card boards that provide good audio playback quality and microphone inputs.

Presently, the system consists of two Raspberry Pi model Bs. The first Rpi is coupled with a Wolfson audio card whose inputs are: 1) a Line IN that is connected to the female audio jack connector (for music playback), and 2) Headset input that is connected to the microphone (for the monitoring system). The second Rpi is coupled with a HiFiBerry DAC+ sound card, a Bluetooth USB module and Wi-Fi USB antenna. The HiFiBerry DAC+ sound card is a digital-to-analog converter specifically designed for the Rpi that will ensure quality audio reproduction. The two Rpis are connected through their Ethernet port and an RJ45 cable.

An aluminum box, out of view from the public contains this key hardware. A second box, for physical connections (i.e. not Bluetooth), contains an analogue knob for gain adjustment, information about the device, and a male 1/8th-inch stereo audio jack. A 1/8th-inch to ¼-inch adapter will be secured to the jack with a zip tie.

The sound system is composed of four 2-way active loudspeakers (with 4" Woofers) fixed to the gazebo's ceiling and aimed toward the ground. Presently, the design will split 2-channel (stereo) audio over two speakers each. As hardware capabilities expand, it may become possible to offer 4-channel audio, but we are currently limited to 2-channels by the Raspberry Pi. We do not view this as a shortcoming of the device considering that most users will bring only stereo audio for playback.

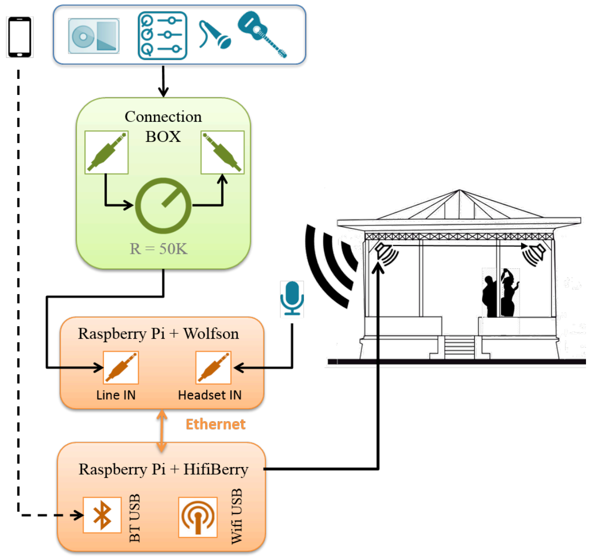

Figure 1: Overview of the connections of the Musikiosk device

2.3 Software Overview

The Rpis run on a Wheezy Raspian distribution patched with a Wolfson card and real-time kernel modules (Linux raspberrypi 3.10.25-rt23+). While there exist dedicated audio distributions for Rpi, such as Volumio, a "clean" distribution was chosen in order to optimize the distribution for our own needs and avoid unneeded services and software.

The Musikiosk software includes both Advanced Linux Sound Architecture (ALSA) and Pulse Audio (PA) apps. The ALSA mixer is used to set our audio inputs and outputs and for gain control and equalization features. The PA server is used to redirect audio sources to audio sinks previously defined in ALSA. The monitoring and limiter features were developed in the Functional AUdio STream (FAUST) language and compiled as ALSA apps.

The Bluetooth features are managed with the BLUEZ package that manages Bluetooth layers and protocols such as authorization, connection, and black-listing of devices by their MAC addresses. Bluetooth's standard Advanced Audio Distribution Profile (A2DP) is used to stream and process the audio from the user's device.

2.4 Meeting Requirements

2.4.1 Size, security, and durability

Musikiosk will operate in a public environment for a long duration (over 1 month.) As such, the device will need a small profile, a discreet casing, and a secure installation. Further, should the device be vandalized, the public-facing parts should be easily replaceable. Lastly, Musikiosk will encounter various weather conditions and should operate stably through them. From a software standpoint, Musikiosk should be able to run stably for long periods without frequent intervention from the team members.

To meet these requirements, Musikiosk is encased in two separate, custom aluminum boxes: one containing the key hardware placed out-of-reach, and one containing audio connection hardware, a gain knob, and messaging/device information, which can be easily replaced. The 4 loudspeakers chosen were selected for their optimal outdoor performance and cost. Further iterations of the device may include more integrated hardware such as a product deployed in the lighting system or a distributed-mode loudspeaker used with the gazebo architectural elements.

2.4.2 Acoustic monitoring, indicators, and recordings

Musikiosk should provide acoustic monitoring to: 1) ensure that playback levels are appropriate in the context of the park activities, and 2) for later comparison with human evaluations of the park soundscape for the development of predictive models and failure analysis. The Musikiosk software should calculate various acoustic indicators (e.g. L_{eq}, L_{A5}, L_{A10}) in real-time and store them for later analysis. Lastly, Musikiosk should have the capability of recording and storing audio for data analysis purposes or for users who wish to record their performances; the default position of this function should be *off* to ensure the privacy of regular users. Although compliance with sound level meter standards is not required, the acoustic monitoring should provide sound level measurements within an accuracy of ±2 dB-A (equivalent to a type-2 sound level meter).

To address these demands, our acoustic monitoring system includes an audio sound card for the acquisition of the microphone signal and in-house software that manages the calculation of the indicators, the calibration, and the data storage and management. The accuracy requirement is achieved with a proper choice of microphone and with a calibration that includes both frequency-dependent and sound level-dependent corrections.

The electret microphone was chosen based on the results of a study **Error! Reference source not found.** on the use of consumer electronics microphones for long-term urban monitoring. They demonstrated that properly calibrated electret microphones resulted in a small additional averaged error (limited to 1 dB-A) and therefore, can be used for long-term outdoor sound level measurement.

While the frequency-dependent calibration aims to flatten the frequency response of the whole monitoring system (including the microphone and the sound card), the sound level-dependent calibration corrects the sensitivity. The calibration algorithm, linear interpolation, and the calibration measurements are described in detail by Dumoulin [14]. The appropriate calculation of the acoustic indicators is conducted with A- and C-weightings, implemented in the in-house software as IIR Filters whose coefficients were designed to meet the requirements from the IEC 61672 standard. Based on the calibrated A and C-weighted $L_{eq,1sec}$ sound levels, the monitoring system provides various acoustic indicators including the equivalent sound level (L_{eq}) calculated over several durations (5, 10 minutes, 1 hour, evening, night) and "sliding" sound levels, which are equivalent sound levels measured over a time-based sliding window. Measurement and recording data are logged in binary files, together with users' connection information and crash reports. To avoid raising privacy concerns, Musikiosk only stores very short audio recordings.

2.4.3 Automatic and autonomous sound level control and operation

As the needs and uses of the park change throughout, the day, week, and season (and for special events, of which there are many in Montreal), the Musikiosk must have a number of operating modes that satisfy concerns based on the context. Further, the sounds of Musikiosk in the standard operating mode should not be clearly audible (or emergent) from the nearby residences.

To address the need for various operating modes, the Musikiosk software includes calendar-based features that permit the device to automatically control and adjust the music playback depending on the time. Sound level threshold and equalization settings can be assigned differently for various periods; overall, early and late hours call for music playback with less low-frequency content and a lower overall sound level. At closure time, the device will automatically shut down following a warning recording.

To meet the requirements for an autonomous sound level control, the music playback software integrates a sound limiter whose input is provided by the monitoring stream. The limiter app performs a downward compression with measured 1-second ⅓-octave band levels and a 10-minute sliding sound level as inputs. Threshold limits were determined in order to provide a maximum sound level of 80 dB-A in the center of the gazebo.

2.4.4 *Wired and wireless connectivity*

Musikiosk is intended for many types of users and devices. As such, it should offer both a wired connection (e.g. for guitar players and older iPod users unfamiliar with Bluetooth), and a wireless connection. Wireless connections should be in two modes, one for the standard user and one for the researcher to access for updates and downloads of the data.

To address the requirement for wireless access, a DHCP server was installed on one of the Rpis and Bash scripts were written to manage the stream coming from the Bluetooth USB module. Thereby, the users can easily connect to a local network, play their music using their own Bluetooth device, and access a web page with general information about the project and take a survey. A restricted wireless access account is also provided for the researchers in order to visualize and download the measurement and recording data.

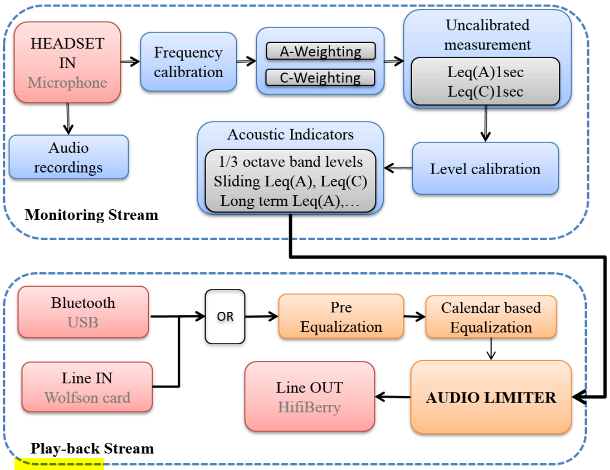

Figure 2: Audio processing components of monitoring and playback streams

3 DESIGN CONSIDERATIONS AND ITERATIVE PROCESSES

Musikiosk is intended for installation in a public park for a period longer than one month. The research will take place in three phases: 1) a pre-installation study, including human evaluations (described in Section 4) and acoustic modelling to understand the park baseline. The Musikiosk technologies should achieve a stable release by that time. Primary system rules, settings, and calendar timings will be determined during this period; 2) an adjustment phase. For the first few weeks of the installation, the rules of the Musikiosk operation will be under scrutiny. Various feedback mechanisms are taken into consideration to adjust the system rules to optimize the device. For example, we will try to determine the best maximum connection time to the device per user (per time-of-day). Comparisons will also be made between the human evaluations and the technical data, such as acoustic indicators to search for potential improvements to the design. Early questionnaires will conduct user needs assessments and observations of interactions with the device for interface improvements. Any feedback and complaints will be addressed directly and quickly; and 3) the research phase. Here, the Musikiosk system operating rules will stabilize. Physical and subjective responses will be collected and compared to determine the core hypotheses from the study.

If there is a noise complaint through the city's traditional 311 reporting service rather than via the researchers, we will follow-up with the person who filed the complaint (if they wish) directly or through our city contacts. We will address individual issues after identifying their reasons for the complaints and consulting logs. In line with the soundscape approach, we aim to improve quality of life via added sound while minimizing negative noise impacts. Thus, we seek to deemphasize the likelihood that these added sounds would be interpreted negatively by the community. In contrast, Musikiosk will afford the sounds the community wishes to amplify. Acoustic models of the park and its nearby sensitive residents have been made to ensure the average maximum level of Musikiosk is not emergent from the noise floor created by the auto traffic and other urban activities at a certain distance.

4 EVALUATING THE MUSIKIOSK SOUNDSCAPE

4.1 A mixed-methods approach

We rely on a combination of data collection methods, given the nature of the user group (e.g. multigenerational/multicultural, different levels of engagement with this particular park, and different contexts for evaluation whether at home or in the park.) The analysis will focus heavily on the comparison of the longitudinal data, especially pre- and post-installation.

4.1.1 *Qualitative evaluations*

To assess the needs and concerns of local residents, the City of Montreal will send mailers on our behalf to local residents with surveys about their park usage habits, music sharing habits, quality of life, relationship with music in public and private settings, common noise complaints, and noise sensitivities. After the project period, follow-up surveys will be sent to measure the impact of Musikiosk on quality of life and park usage. Other methods to address the public-at-large are public consultations at community meetings to discuss park needs and concerns. Local residents also communicate with the city via the 311 information and reporting hotline. We will attempt to follow-up with any cases relevant to Musikiosk.

To evaluate park users, we will use a two-part approach: 1) short questionnaires about experience, satisfaction and activity; and 2) observations of the different activities conducted in the park. For example, a standard short soundscape evaluation would include ratings along three scales that generally capture the majority of the variance of urban soundscape evaluations: pleasantness, eventfulness, familiarity [16]. Questionnaires will also ask about the activities being conducted during the evaluation and the association of the participant to the Musikiosk user. Studies have shown a difference in evaluations between music types, whether it is live or not. For example, Guastavino [7] reported positive evaluations of live music and negative evaluations of music played back over speakers in the context of urban soundscapes, possibly due to the presence of the musician. The comparison of these data with those collected after the installation will provide insight on how Musikiosk is able to affect soundscape evaluations via a change in activity, musical engagement, or quality of life.

In addition we will invite park users and residents to provide feedback on the Musikiosk via a variety of collection methods including: automatic questionnaires for anyone who has connected to the system via Bluetooth, signs adjacent to the device directing them to a website containing a questionnaire, and information in the public mailers directing them to the same website or to call the city hotline.

4.1.2 Physical measures

We will compliment the resident and park user surveys with objective measures of the system usage such as system logs and acoustic measurements. Data analysis will reveal which of the acoustic indicators (e.g. L_{eq}) have the highest predictive power for soundscape evaluation, and those results will be compared to findings from the literature, keeping the unique musical and urban context in mind. Also, any noise complaints via the city hotline or other means will be evaluated with respect to whether the offending use was exceptional or habitual. We will also make use of existing music information retrieval (MIR) toolboxes to gather information about genre type or song name of the content being played.

5 CONCLUSIONS

Musikiosk will play with traditional notions of music sharing, with a twist, by providing a venue accommodating music sharing back in the public domain. This project will be of the firsts to systematically investigate how a music installation affects the use of a public space and the experience of people in its soundscape. The proposed device and mixed-methods approach will provide new insights on how to best integrate the perspective of the users and evaluate a music installation in public urban spaces. The comparison of human judgments and acoustic measurements will provide empirical grounds for validating acoustic indicators in an urban context with different groups of users (e.g. residents, tourists, musicians and park users).

Multiple parties will stand to benefit from the research outcomes: the researchers have unique access to manipulate the soundscape and collect evaluations from multiple types of users and integrate feedback; the users and residents may benefit from increased musical and cultural opportunities provided in the spaces they use; and the city will benefit from a better understanding of urban needs and ways to improve quality of life. We further anticipate outcomes for improving urban design techniques that integrate added sound with a positive intention and outcome.

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