

# MUSIKIOSK: A SOUNDSCAPE INTERVENTION AND EVALUATION IN AN URBAN PARK

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Musikiosk is an interactive music installation and environmental monitoring station developed for urban parks by CIRMMT, ÉTS, McGill, and the City of Montreal. We describe the development of the technology and propose a comprehensive mixed-methods research program to evaluate its impact on the community. Environmental monitoring via an ambient microphone input provides information about system usage, physical measurements of the acoustic environment, and playback levels. A survey with park users, non-users, and residents will be conducted before and after the installation to empirically evaluate the urban sound intervention and best integrate the users' perspective throughout its lifecycle. 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 University 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 an ambient 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 soundscape, accompanies the installation to try and capture measurable impacts, positive and negative, of Musikiosk on the community. This paper describes the technology that has been developed for Musikiosk and the research program that will take place in the summer of 2015.

## 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 proposed Musikiosk technology is a public-facing audio input that allows users to connect their own wired or wireless musical device, like a

personal music player or musical instrument, and play it through a high-quality outdoor sound system that is provided. 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 offers a number of modes: standard, 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, provides information about ways to update the system based on user feedback or as problems arise and contributes toward theories of soundscape intervention and evaluation and the role of activity in those judgments [5].

### 1.2.1 Monitoring with acoustic indicators

A microphone placed within the gazebo, next to the Musikiosk hardware, collects a number of acoustic indicators and stores them on a memory card. Brocolini et al. [6] 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  $MI_{L>Lx}$ ). In the adjustment phase of Musikiosk (described in Section 3), we will 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 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 only the negative impacts of noise, thus they 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 just noise-focused acoustic indicators toward ones that capture positive effects. This need necessitates an interdisciplinary approach that can capture the positive benefits that the intervention has on the community (residents, park users, nearby business) – this approach is known as *soundscape*. Soundscape is defined as the acoustic environment as perceived and understood and/or experienced, by people or society, in context [7]. 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 [5][8][9]. Calls have been made for mixed-methods approaches to evaluate the quality of acoustic environments, especially 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. Rather, much more of the variance (about 74%) of soundscape judgments can be explained by listeners' ratings along three scales: pleasantness, eventfulness, and familiarity [12]. We propose that Musikiosk can contribute toward the further development of appropriate acoustic indicators while extending the understanding of context in soundscape evaluations.

## 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 2.4:

- 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 recording audio samples on a digital memory card;
- 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, it is important to understand that the Musikiosk will be installed in a busy urban space with a light residential context and that the device is intended for a general, rather than tech-savvy audience.

## 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 [13] and Citygram [14] used the BeagleBone Black board (BeagleBoard.org Foundation, Richardson, TX) and an Android Mini PC, respectively, for acoustic sensing, Musikiosk uses Raspberry Pi (Raspberry Pi Foundation, UK), dubbed “Rpi”, because of available add-on sound card boards that provide good audio playback quality and microphone inputs.

Presently, the system consists of an Rpi (model B) coupled with a Wolfson audio card (Wolfson Microelectronics, Edinburgh, UK), a USB sound card (Sound Professionals, USA), a Bluetooth USB module and Wi-Fi USB antenna. The monitoring is processed by the USB audio card which comes with an electret microphone (signal to noise ratio: 62dB; maximum pickup range: 12m; dynamic range: 81 dB; frequency response: 20-20,000 Hz) attached to it. The playback stream is enabled by the Wolfson line connectors for both output and direct input.

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 1/8” stereo audio jack. A 1/8” to 1/4” adapter will be secured to the jack with a zip tie.

The sound system is composed of four 2-way active loudspeakers (with 4” electrodynamic loudspeakers) fixed to the gazebo’s ceiling at approximately 4 meters high. In the current design, the stereo output is sent to the two pairs of loudspeakers. The gazebo is composed of acoustically reflective materials (timbers, wooden panels, and a concrete floor). As any temporary acoustical treatment could not be added within the gazebo ceiling, flutter echoes were avoided by aiming the speakers toward the outer edge of the gazebo floor. See Figure 1 for an overview of hardware components.

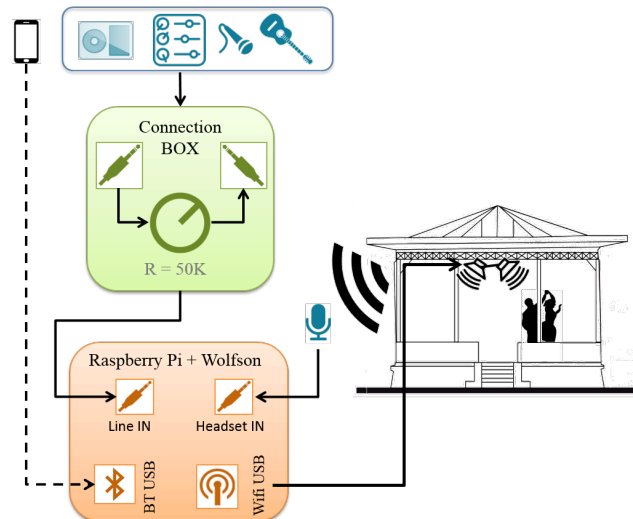


Figure 1: Overview of the connections of the Musikiosk device

## 2.3 Software Overview

The Rpi’s operating system (OS) utilizes a Debian-based distribution, called Raspian Wheezy, patched with real-time kernel modules (GNU/Linux raspberrypi 3.10.25-rt23+) to support the Wolfson audio card. While there are comprehensive dedicated audio distributions readily available for Rpi such as Volumio, a minimal distribution was chosen for Musikiosk so that it could be tailored to our exact needs and in order to avoid unneeded services and software components.

The Musikiosk software is programmed using the Advanced Linux Sound Architecture (ALSA), Pulse Audio (PA) apps, and Python scripts. 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 coded in Python. Features were then automatized with Bash scripts.

The Bluetooth features are managed with the BLUEZ package that manages Bluetooth layers and protocols such as authorization, connection, and blacklisting 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 Functional Requirements

The current section details Musikiosk’s functional requirements and presents the solutions that have been implemented or proposed to address them. Figure 2 presents, in a schematic, the different processing pieces and components of the developed software.

### 2.4.1 Size, security, and durability

In terms of physical requirements, Musikiosk will need to operate in a public environment for a long duration

exceeding one month. For this reason, the device will need a small profile, a discreet casing, and a secure installation. Further, should the device be tampered with or vandalized, the publicly visible parts should be easily replaceable. Lastly, Musikiosk will encounter various weather conditions and should operate in a stable manner through them. From a software standpoint, Musikiosk should be able to run in a stable manner for long periods without any maintenance.

To meet these requirements, Musikiosk is encased in two separate, die-casted aluminum boxes: one contains the core hardware and is placed out-of-reach, and the other contains audio the audio connection hardware, namely a gain control potentiometer and knob, and an explanation notice. The four loudspeakers that were chosen were selected for their superior outdoor performance and low cost.

#### 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 acoustic monitoring should provide sound level measurements accurate to  $\pm 2$  dB-A, so as to be equivalent to an ANSI type-2 sound level meter [15].

To meet these requirements, and as previously presented in Section 2.2, Musikiosk's 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, calibration, and data storage and management. The accuracy requirement is achieved with the choice of microphone and with a calibration that includes both frequency-dependent and sound level-dependent corrections. The selected ambient microphone, an electret microphone, was chosen based on the results of a study on the use of consumer microphones for long-term urban monitoring [16]. It was demonstrated that the use of properly calibrated electret microphones led to a small additional averaged error, limited to 1 dB-A, and therefore, can be effectively used for long-term outdoor sound level measurement.

While the frequency-dependent calibration aims to flatten the frequency response of the whole measuring chain (including the microphone and the sound card), the sound level-dependent calibration only corrects the measurement chain sensitivity. The calibration algorithm, linear interpolation, and the calibration

measurements that were used are similar to the ones described by Dumoulin [17]. Currently, the effective sound pressure levels are expressed with A- and C-frequency weighting filters, implemented in the in-house software as IIR Filters whose coefficients were designed to meet the requirements of the IEC 61672 standard [18]. Based on the calibrated A- and C-weighted  $L_{eq,1sec}$  sound levels, the monitoring system provides further 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 records and stores short audio recordings of less than 10 seconds that will later be used for soundscape classification.

#### 2.4.3 Automatic and autonomous sound level control and operation

As the needs and uses of the park change throughout the days, weeks, seasons, and special events, the Musikiosk must offer various operating modes that fulfill the users' needs dependent on the context of use. From the nearby residents' perspectives, it is crucial that the sounds generated by the Musikiosk installation in the standard operating mode do not significantly emerge from the ambient noise perceived.

To address the need for various operating modes, the Musikiosk software includes calendar-based features that enables the device to automatically control and adjust the music playback level depending on the time-of-day, the day of the week, and the type of activities scheduled. Sound level upper limits and frequency equalization settings can be assigned differently for the different periods of the day. In general, early and late hours call for music playback with less low-frequency content and a lower overall sound level. After curfew, the Musikiosk automatically shuts down after a prerecorded warning message has been played on the loudspeakers.

To meet the requirements for an autonomous sound level control, the music playback software integrates a sound level limiter, which is continuously monitoring the audio stream. The limiter modules perform an adaptive gain control of the output (AGCo) based on the gain of the input signal (from the line IN or the Bluetooth stream) and measured 1-second  $L_{eq}$ . Playback limits were set in order to provide a maximum sound level of 80 dB-A at the center of the gazebo, which is at least 20 dB-A above the background noise.

#### 2.4.4 Wired and wireless connectivity

Musikiosk is intended for many types of users and devices. As such, it should offer both a Bluetooth wireless connection and a wired connection (e.g. for guitar players and older users of personal music players unfamiliar with Bluetooth technologies.) The Bluetooth wireless connection should have two modes, one *user* mode for the user to send their music stream to the Musikiosk and one *administrator* mode for the researcher to access the Rpi for software maintenance and also for the download of logged data and audio recordings.

To address both of these requirements 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. In the *user* mode, the users equipped with a recent smartphone or tablet will first discover a “Musikiosk” wireless network access point (“hot-spot”). Next, they will be presented with a light web page that gives some general information about the Musikiosk project and produces a link to an online survey. Finally, they will be instructed to play their music using their own Bluetooth-enabled device. A restricted wireless access account is also provided and can enable the *administrator* mode in which the researchers can access the Rpis and download the recorded measurement and audio data.

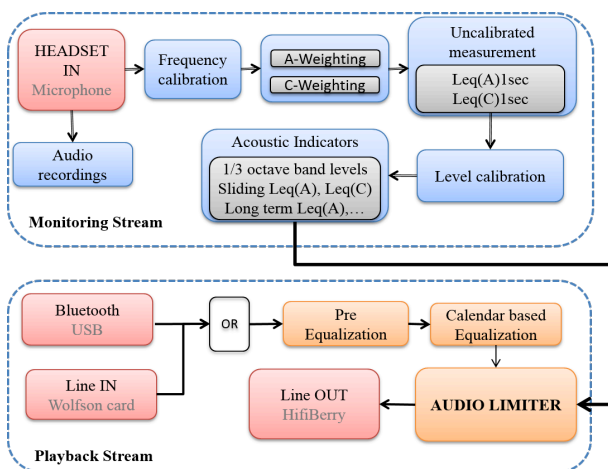


Figure 2: Audio processing components for the monitoring and the playback of audio streams

### 3 DESIGN CONSIDERATIONS AND ITERATIVE PROCESSES

The Musikiosk device has been designed such that it can operate in a public park for a period of one month or more. The work presented in this paper to this point has been completed in preparation for the accompanying research, which will begin in the late spring of 2015. The research will take place in three phases: 1) a pre-installation study, including acoustic modeling to

understand the park’s initial conditions (described here in Section 3) and human evaluations (described in Section 4). 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. 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 and collection of acoustic indicators. Early questionnaires will focus on user needs assessments and observations of interactions with the device to look for interface improvements. Relevant feedback will then be addressed; and 3) the research phase. Here, the Musikiosk system operating rules will stabilize. Physical and psychological 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 reporting service (311 on a local telephone) 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 the community could interpret these added sounds negatively. In contrast, Musikiosk will afford the sounds the community wishes to amplify.

To set the initial conditions, acoustic measurements of the park have been taken (see Figure 3 for an example.) Maximum output levels will be modeled after the nearby traffic noise profile over the course of the week.

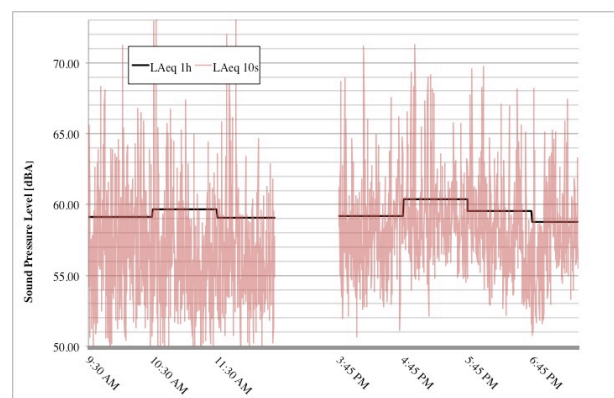


Figure 3: Background noise measured at the center of the gazebo on a single day. Levels are A-weighted  $L_{eq}$ s, time-weighted over 10 seconds and 1 hour

## 4 EVALUATING THE MUSIKIOSK SOUNDSCAPE

### 4.1 A mixed-methods approach

While Musikiosk has been designed and tested, we would also like to propose a method for evaluating the device and its impacts during its upcoming installation in the summer. 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 pre- and post-installation data.

#### 4.1.1 Qualitative evaluations

To evaluate park users, we will use a two-part approach: 1) short questionnaires about experience, satisfaction and activity conducted in-person by the researchers; and 2) observations of the different activities conducted in the park. The questionnaire will ask for: perceptions of the park and its core activities; ratings of soundscape pleasantness, eventfulness, familiarity [12]; perceived dominant sound sources and soundmarks [19]; evaluations of (soundscape) affect and mood, including soundscape restorativeness [20]; demographic information; as well as satisfaction with Musikiosk for users of the device. The questionnaire will serve as a core link to soundscape evaluation. For example, Guastavino [8] 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. This data is not readily observable with acoustic indicators. 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.

To assess the needs and concerns of local residents, we will send mailers to local residents directing them to an online questionnaire 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 commonly communicate with the city via an information and reporting hotline (the 311 service.) We will attempt to follow-up with any cases relevant to Musikiosk.

In addition to the methods listed above, we will invite park users and residents to provide feedback on the Musikiosk via a variety of collection methods including: the aforementioned 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 complement the resident and park user surveys with the physical measures enumerated in Section 2 and system logs. Data analysis will reveal which of the acoustic indicators 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. We will also make use of existing music information retrieval (MIR) toolboxes [21] on the short recordings taken 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 among 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 coupled with a mixed-methods research 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.

Additional information can be found at <http://www.musikiosk.org>.

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