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Shaping urban soundscapes through sound art: a case study in a public square exposed to construction noise

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This paper reports the main findings of an in situ study involving the design and evaluation of a sound installation in a public square in Montreal exposed to construction noise. 357 questionnaires were administered to public space users in July and August 2019. We compare the responses collected in the presence or absence of the installation to investigate its effect on soundscape evaluations. The results show that the presence of the sound improved the soundscape of the public square, particularly when the public square was exposed to construction noise.

INTRODUCTION

Noise exposure can have detrimental effects on health and quality of life. Cities often rely on a reduction in sound level to reduce noise pollution [16, 11]. However, sound level measurements do not always correspond to human judgments of sound quality. Soundscape refers to "[the] acoustic environment as perceived or experienced and/or understood by a person or people, in context" [6, 12, 18, 10]. Considering sound as a "resource" rather than a "pollutant", the soundscape approach, developed as a research field over the past 20 years, uses a wide range of methods to investigate and enhance the human experience of sound environments [1, 6].

Specifically, recent studies suggest that added sound, and particularly sound art in public spaces, can have a positive influence on sound environment evaluation. It has been reported that people who take a break stay significantly longer and do more activities such as chatting or eating when sound is added to the environment [13, 2]. Others have observed that music in public spaces influences crowd density and walking patterns [15]. Analysing open-ended interviews, Cerwén reports that users' experience of the sound environment improved when adding forest sounds to a urban place [7]. Other studies showed that sound installations can also increase ratings of *eventfulness* and *excitement* [9], or improve *pleasantness*, *vibrantness* and *eventfulness* [21, 5].

Soundscape is a multifaceted phenomenon and hence cannot be measured with a single method or unit [12]. A wide range of methods are used for soundscape evaluation, following various paradigms. Among them, soundscape scales have been defined to measure the perception of specific attributes of the acoustic environment. Axelsson proposed the *Swedish Soundscape-Quality Protocol* (SSQP), an eight-item evaluation (*pleasant, unpleasant, eventful, uneventful, calm, monotonous, vibrant, and chaotic*) [3]. These scales were derived from a factor analysis of ratings collected in a laboratory experiment. More recently, Payne and Guastavino validated four sets of scales to assess the restorative po-

tential of sound environments in terms of *being-away*, *extent-coherence*, *compatibility* and *fascination* [17].

The study reported in this paper was conducted as part of the Sounds in the City partnership¹, a collaboration between researchers from McGill University, the City of Montreal, Audiotopie² (an artist cooperative specializing in urban audio experiences) and public and private sector partners. The research took place in a new public square called the *Place des Fleurs-de-Macadam* in Montreal's Plateau-Mont-Royal borough. The goal of this study was to improve the soundscape of the new public square through a sound installation created by Audiotopie. This collaboration benefits both the research team by allowing controlled and guided sound design conditions, and the artists by providing a framework for systematically evaluating the impact of a sound installation. The present study builds upon results from a previous collaboration conducted the year before (summer 2018) in the same square, where the presence of a sound installation significantly changed soundscape assessments by, for example, reducing perceived loudness [20]. The present study evaluates changes brought about by another soundscape intervention delivered through a sound installation in a more challenging situation, namely in the vicinity of a major, albeit temporary, construction site.

METHODS

CONTEXT

The recently inaugurated public square *Fleurs-de-Macadam*, located at 962 Mont-Royal Avenue East in the Plateau-Mont-Royal borough, is shown in Figure 1. In the summer 2019, major road construction work – and associated construction noise – took place from early July to early August on Saint-André Street, one block away from the square. Consequently, traffic on Mont-Royal Avenue, the main commercial road abutting the square, was significantly reduced during this time.

The construction work took place only during a portion of the sound installation's presence, and there are therefore questionnaires collected in the space with and without construction (noise) while the sound installation was both present and not.

SOUND INSTALLATION

The sound installation was created by the sound design cooperative *Audiotopie*, and was an iteration on a previous collaboration with our research team [20]. The system made use of an eight-speaker configuration called *ESSA/M* (see figure 3) and was designed to play original compositions over long time-frames. The setup consisted of a loudspeaker, an amplifier and a playback system on a chip embedded inside a protective ABS tube and serving as a baffle (see Figure 2). At a high level of

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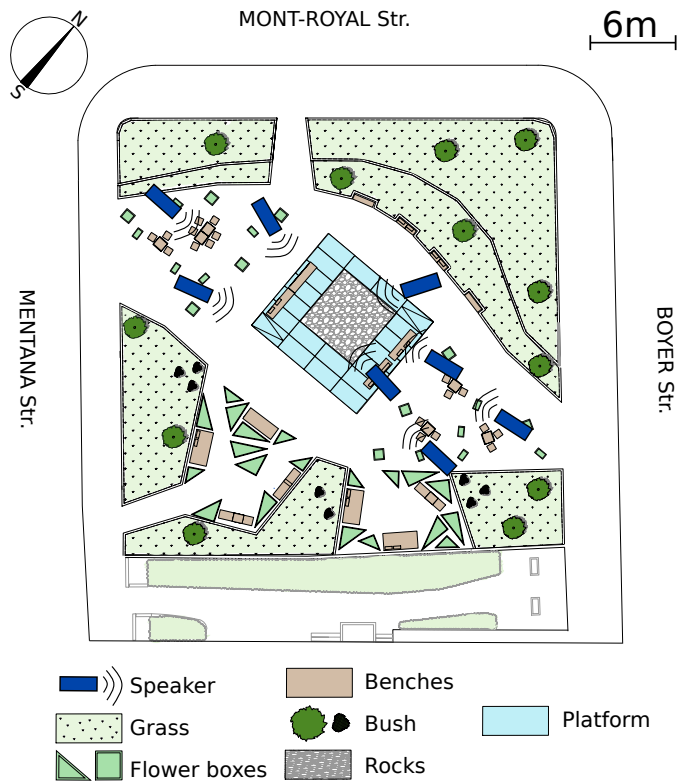


Figure 1: Overview of the Fleurs de Macadam square, 2019's design

abstraction, the setup is composed of two types of devices, main and secondaries. The main sends signals to the secondaries and tells them to play their respective audio – WAV – files at a specific time of the day. Using the main-secondary architecture allows for wireless synchronization of multiple speakers, and therefore the system is able to create a complex polyphony as each secondary can play a different track at the same time. Both the main and the secondary use a Teensy 3.2 microcontroller connected to a Xbee radio transceiver to communicate. The main is connected to an external real-time clock so it knows when to send playback request to the secondaries. It also uses an SD card shield where the instructions (i.e. time of the day to send a request to the secondaries) are stored and accessed at run-time. All the secondaries use an audio shield with an SD card slot allowing them to play a variety of tracks when required to. The secondaries send the audio information from the audio shield to an amplifier. The Teensy 3.2 were programmed using the Arduino platform, an Open-Source development platform for microcontrollers and embedded systems.

COMPOSITION

Composer Simone D'Ambrosio created the sound installation, using a compositional strategy identified as *oppositional*, where composed sequences are meant to emerge from the existing background sounds as clearly noticeable events [14]. The composition relied on acousmatic sounds (that cannot be associated with an identifiable source or originating cause) and their motion in space. This strategy resulted in the provision of mostly synthetic sounds following complex trajectories across multiple speakers, which had the goal of giving users an exploratory or playful sensation of the space.

In addition, an analysis of the activities performed in the public square the previous summer revealed significant differences in park use between different times of the day [8]. For example, users in the afternoon tended to mostly use the space for relaxing purposes, while a large



Figure 2: One of the 8 speakers used in the sound installation.

proportion of users used it for socializing in the evening. Responding to these changes throughout the day, the composer designed material that evolved over time in a way that attempted to support the primary uses, varying the density of sound events to match the ambience of the square. The installation's sound level was calibrated by ear to be clearly audible but not disruptive, with a 3 dB decrease starting in the evenings at 7 pm. This decrease was selected based on a previous analysis of long-term sound level measurements in the square (see [8] for further description of this analysis).

The sound material remained sparse, with discrete events and many rests in between. During each period, various sound loops were presented and repeated through each speaker independently, as illustrated in Figure 4. Seven distinct blocks of audio content were the basis of the composition which evolved throughout the day by varying the density, times, and speakers over which the seven blocks were played.

DATA COLLECTION METHOD

Questionnaires To assess the influence of the sound installation on soundscape assessments, the research team collected questionnaires across two conditions (no installation - **OFF**; sound installation - **ON**), covering both weekdays and weekends from early morning to late evening. The Questionnaires included 12 five-point Likert scales (from *strongly disagree* to *strongly agree*) described in table 1 as well as basic demographics. While the results refer to the English wordings for convenience, participants were able to complete the questionnaire entirely in English or in French.

Section	Variable	Description
SSQP [3]	Pleasant Calm Monotonous Vibrant Chaotic Eventful	
Restorativeness [17]	Being-away Fascination Compatibility Extent-coherence	Spending time in this soundscape gives me a break from my day-to-day routine Following what is going on in this soundscape really holds my interest It is easy to do what I want while I am in this soundscape The sounds fit together to form a coherent soundscape
Appropriateness [22]	Appropriate	Appropriate for my activity
Loudness	Loudness	I find the sound level here to be high

Table 1: Description of the soundscape scales used in the questionnaire.

This study focuses on the between-groups comparison of the scale ratings in the presence and absence of the sound installation, specifically investigating the influence the composition during construction work hours. A MANOVA using Pillai's Trace followed by univariate ANOVA



Figure 3: Place des Fleurs de Macadam during the sound installation on (summer 2019). Photo credit: Valérien Fraisse.

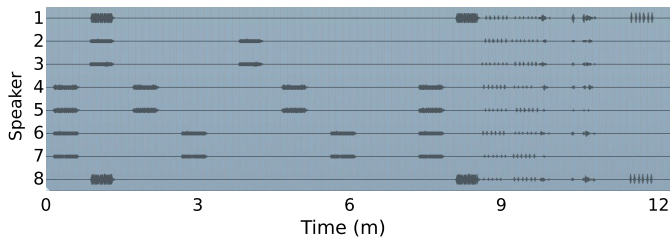


Figure 4: Excerpt of the audio tracks for each speaker.

analyses were performed on the scale data, as well as Welch post-hoc t-tests (using Holm's p-value adjustment).

Participants 357 respondents (mean age \approx 35.7; SD \approx 13.8, min=18, max=78; male = 176, female = 175, gender unreported = 6) filled out the questionnaire on site. Participants were approached about taking the paper-based questionnaire after having already been in the space for a few minutes. Therefore, in the construction conditions, all participants had been exposed to construction noise. The number of collected questionnaires for each condition is provided in Table 2.

Groups	Sound Installation	N
All respondents	ON	206
	OFF	151
During construction hours	ON	60
	OFF	43

Table 2: Number of questionnaires administered by condition.

RESULTS

INFLUENCE OF THE SOUND INSTALLATION

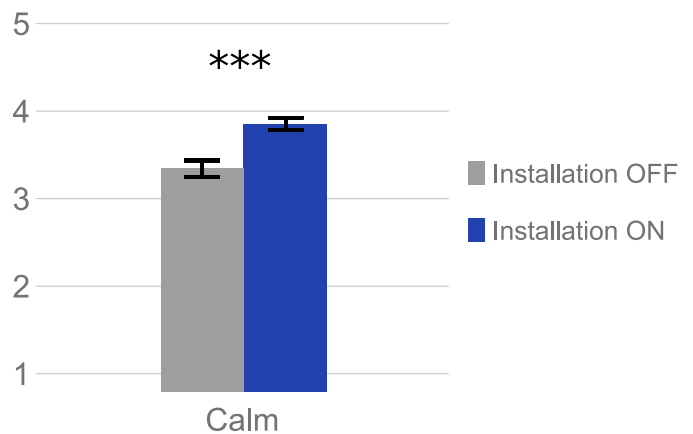


Figure 5: Calm: Comparing control condition **OFF**, and sound installation condition **ON**. Mean and standard error.

Legend: *: $p < .05$; **: $p < .01$; ***: $p < .001$

Using the 12 soundscape evaluation scales from the questionnaire as dependant variables, two MANOVAs were performed between conditions **OFF** and **ON** ($N = 357$) to evaluate the influence of the sound installation on soundscape appraisal. We plan the data collection to balance the number of participants across conditions as shown in Table 2. Subsequently, we evaluated the effect of the sound installation across all

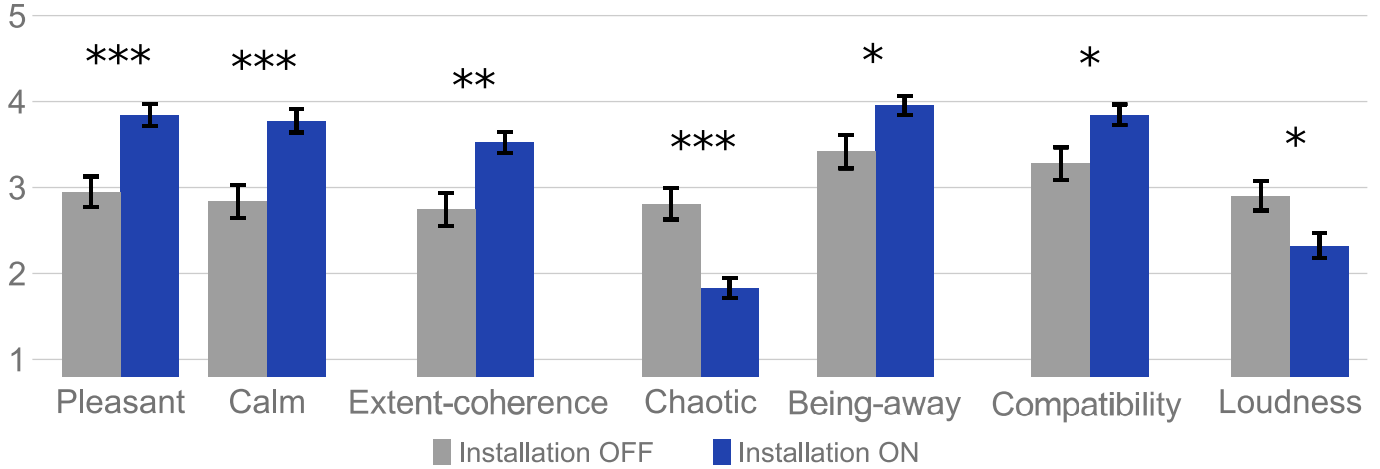


Figure 6: Effect of sound installation during construction time: comparing condition **OFF** with sound installation condition **ON** during construction work hours. Mean and standard errors of scales significantly affected by the installation.

Legend: *: $p < .05$; **: $p < .01$; ***: $p < .001$

times slots and construction conditions. There was a significant effect of condition ($F(12, 344) \simeq 4.00, p \simeq 8.23 \times 10^{-6}$) on soundscape assessment. However, separate univariate ANOVAs on the outcome variables revealed that condition had a significant effect only on the *calm* scale ($F \simeq 20.5, p \simeq 1.42 \times 10^{-4}$). In comparison with the control condition **OFF** and as shown figure 5, post-hoc t-tests revealed that the sound installation resulted in an increased rating of *calm* ($t \simeq -4.36, df = 298.2, p = 1.85 \times 10^{-5}$).

INFLUENCE OF THE SOUND INSTALLATION DURING CONSTRUCTION HOURS

A previous report showed that, in isolation, the aforementioned construction work had a significant impact on soundscape assessment, namely that it decreased *pleasant* and *extent-coherence* while increasing *chaotic* and, to a lesser extent, perceived loudness [8]. The remainder of the results focus on the effects of the sound installation during the construction period, which were found to be more substantial than the control condition. The same statistical analyses as before were performed, but focused during construction work, which was from 7am to 3:30pm on weekdays.

According to a MANOVA between conditions **OFF** and sound installation **ON** ($N = 103$), the composition also had a significant effect on soundscape appraisal **during construction work hours** ($F(12, 90) \simeq 4.17, p \simeq 3.43 \times 10^{-5}$).

Separate univariate ANOVAs revealed that during construction work hours, the installation had a significant influence on *pleasant* ($F \simeq 17.6, p \simeq 6.5 \times 10^{-4}$), *chaotic* ($F \simeq 22.4, p \simeq 8.66 \times 10^{-5}$), *calm* ($F \simeq 17.2, p \simeq 7.11 \times 10^{-4}$) and *coherence* ($F \simeq 12.5, p \simeq 5.51 \times 10^{-3}$). Despite not being significant after the family-wise error correction, the scales *being-away* ($F \simeq 6.5, p \simeq 7.86 \times 10^{-2}$), *compatibility* ($F \simeq 7.1, p \simeq 7.30 \times 10^{-2}$) and *loudness* ($F \simeq 6.7, p \simeq 7.86 \times 10^{-2}$) also seem to be impacted by the sound installation.

Post-hoc t-tests between control condition **OFF** and sound installation condition **ON** confirmed that the installation led to a significant increase of *pleasant*, *calm* and *extent-coherence* and a decrease of *chaotic*. To a lesser extent, the installation also led to a significant increase of *compatibility* and *being-away* while reducing the perceived loudness (see table 3 and figure 6).

	t	df	p
<i>pleasant</i>	-4.07	80.8	1.06×10^{-4}
<i>chaotic</i>	4.52	74.31	2.29×10^{-5}
<i>calm</i>	-4.02	80.05	1.30×10^{-4}
<i>extent-coherence</i>	-3.38	74.54	1.16×10^{-3}
<i>being-away</i>	-2.39	68.81	1.95×10^{-2}
<i>compatibility</i>	-2.54	74.03	1.33×10^{-2}
<i>loudness</i>	2.58	90.67	1.14×10^{-2}

Table 3: Effect of sound installations during construction work hours: post-hoc t-tests between conditions **OFF** and **ON**

DISCUSSION

We suppose that the demonstrated increase in *pleasant*, *calm*, *extent-coherence*, *being-away* and *compatibility*, and a decrease of *chaotic* and *loudness* correspond to *positive* outcomes for users of a public space, especially in light of users' exposure to construction noise. These changes were demonstrated in the presence of added sound. More sound in public spaces (including added sound) has traditionally been associated with negative outcomes in the environmental noise paradigm; yet the literature is increasingly demonstrating benefits of added sound in evaluations of the soundscape of public spaces (e.g. [21, 9, 1]). The benefits of the added sound were, in fact, augmented in the presence of construction noise, which is traditionally associated with unpleasant soundscape evaluations. These outcomes suggest that a sound intervention can be beneficial even in a soundscape containing undesirable sounds. Given that the sound material composition remained sparse, and that its sound level did not emerge noticeably above the background sound levels (i.e. the presence of the sound installation could not be measured with a sound level meter performing 10-minute measurements), we assume that it did not provide energetic masking of nearby sounds. Rather, the sound installation can be thought of as drawing attention to positive sounds, leading to a form of informational masking.

Comparing these results to our 2018 study (using 4-speaker installations and in the absence of construction noise), we observed the same beneficial effects on perceived loudness, calm and being-away [20]; but presently, we observed the additional positive effects on

extent-coherence, compatibility, pleasantness and reduced evaluations of chaotic in the presence of construction noise. It should be noted, however, that the space had a different, temporary visual design in previous iterations.

On methodological grounds, the questionnaire demonstrated the ability of the SSQP [3], the PRSS [17], as well as the perceived loudness and appropriateness scales [22] to capture changes in soundscape evaluations during a public space intervention.

It should also be noted that the construction site was located about a block away, hence future research is needed to investigate whether composed, added sounds could be considered as mitigation measures construction sites that are closer or further away or have a larger or smaller scale. In addition, the study was performed in a gentrified, wealthy commercial and residential borough, in an area exposed to both human, traffic and construction sound sources. While the installation led to positive outcomes in this very specific socio-cultural and acoustical context, it may not influence soundscape the same way in other situations.

CONCLUSION

Although the summer 2018 installation had already pointed to a beneficial effect of added sound on soundscape evaluations in a similar context [20], the study reported here demonstrates the ability of a sound installation to benefit soundscape assessments in an area exposed to undesirable sounds from construction work.

Overall, this case study highlights the potential benefits for cities and urban planners to consider the role of sound expertise as well as sound art interventions in enhancing noise exposed spaces and improving the overall quality of life. While being much less expensive than noise treatment, sound installations can indeed enhance the pleasantness of a space, generate animation, cultural exchanges and promote composers. In light of the results, the intervention, while delivered in the auditory modality could be characterized as having an overall effect on user experience. For built environment professionals, such evidence suggests that sound should not be considered in isolation from other factors but rather integrated with other aspects of the urban experience (e.g. visual surroundings, activities, environmental conditions) [4]. Future directions will explore ways to integrate interactive installations to further enhance visitors' experience.

Future work will integrate findings from other methods used for this study, including other factors from questionnaires (person-related and situational factors), short-term and long-term acoustics measurements, video observations and a comparison with other sound installation in the same space.

This study, along with previous work conducted on this site [20] as well as other pocket parks in Montreal [21, 19], converge to show that urban soundscape can be improved using appropriate added sounds.

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