

## Post-hoc analysis of two temporary acoustic shelters in London

Tin OBERMAN<sup>1</sup>; Bojana BOJANIĆ OBAD ŠĆITAROCI<sup>2</sup>; Kristian JAMBROŠIĆ<sup>3</sup>

<sup>1</sup> Faculty of Architecture, University of Zagreb, Croatia

<sup>2</sup> Faculty of Electrical Engineering and Computing, University of Zagreb, Croatia

<sup>3</sup> Institution, Croatia

### ABSTRACT

The research focuses on two temporary pavilions designed as acoustic shelters in an urban open space: the Serpentine Gallery Pavilion built in the forecourt of the Serpentine Gallery in Kensington Gardens in 2011 and the Be Open Sound Portal pavilion built at Trafalgar Square in 2012, both heritage sites in London. Swiss architect Peter Zumthor designed the former pavilion, while the latter was designed by the English firm Arup. It was recognized that the same soundscape design model - an acoustic shelter - was applied in open spaces of a different aural context. Both were dismantled before the time of this research. With an aim to show the types of soundscape from which acoustic shelters in an urban open space could shield, monaural onsite measurements were performed in October 2015 to analyze aural context differences between the immediate surroundings of the two former pavilions. The difference is clearly visible in the frequency of sonic events, their spectral composition and average sound pressure levels.

Keywords: soundscape, urban open space, survey

### 1. INTRODUCTION

In an urban open space citizens are exposed to a vast range of sounds which are largely uncontrolled byproducts of various activities, most commonly falling into the category of noise, or signals and commercial sounds. Accordingly, urban open spaces and their soundscapes directly influence the quality of city life. Acoustic comfort is therefore required not only for indoor spaces but also for urban open spaces.

Noise mitigation, however, cannot be the sole answer to this issue because acoustic irritation does not depend only on the perceived soundscape level but also on its content. Consequently, quietness is not a necessary precondition for achieving acoustic quality. The soundscape of an urban park and the soundscape of an urban square are expected to be of different quality. While an urban park could be pleasantly calm, the soundscape of an urban square could be joyfully eventful, as suggested by Brown (1). On the other hand, both could also be of low acoustic quality.

What are the specific architectural design tasks with regard to soundscape interventions in an urban open space? Temporary public soundscape interventions are common in the form of temporary public art pieces with a strong architectural dimension. They follow the development of the model of temporary public facilities intended for leisure and public life, as suggested by the discourse of history of architecture (2).

Soundscape, as a significant factor of urban ambiance, contributes to the spirit of the place, therefore also to constructing the identity of cultural heritage (3). Soundscape interventions in historical urban open spaces of a cultural heritage value are rarely conceived primarily to enhance the urban soundscape. They intertwine contemporary sound art, music, acoustics and urban design (4).

The development of the integral approach, which would include the planning of both quantitative and qualitative factors for the enhancement of an urban soundscape, is the focus of the soundscape research discipline. It is most commonly based on combining measurements and a questionnaire in the research phase (5). Several approaches and tools have been developed towards the useful soundscape

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<sup>1</sup> tin.oberman@arhitekt.hr

<sup>2</sup> bbojanic@arhitekt.hr

<sup>3</sup> kristian.jambrosic@fer.hr

assessment and significant efforts are recently being made towards its standardization (6).

## **2. ACOUSTIC SHELTER - SOUNDSCAPE DESIGN MODEL**

Three general principles of soundscape intervention in an urban open space have been widely recognized: 1) lowering sound pressure levels of unwanted sound sources (most commonly by building noise barriers); 2) protecting and attentively treating sound sources of valuable soundscape elements; and 3) adding new sound sources.

Soundscape interventions in an urban open space, especially the ones that consider adding new sound sources, are commonly characterized by an artistic approach. They could be considered an enhancement of a public space in the same way as a sculpture placed in a square would. This artistic value is not necessarily reserved to the additive principle; it can also be characteristic of the principle of subtracting sounds (lowering sound pressure levels of unwanted sounds). This case is probably 'the most inherently architectural' of all soundscape intervention principles.

It is presumed that, besides the potential value as public art, an acoustic shelter can enhance the acoustic experience of an urban open space at the following levels: 1) it creates an area characterized by lesser acoustic annoyance; 2) it creates an opportunity for a richer, more dynamic experience of an urban open space while the passerby moves through different acoustic environments. An acoustic shelter is expected to be located in urban open spaces characterized by a significant level of noise and/or significant social presence.

Two general types of acoustic shelters can be recognized: 1) the ones created by the linear element acting as a sound barrier; 2) the enclosed ones wrapped by the sound barrier (5). This research focuses on the former, being the more obvious one.

Examples of enclosed acoustic shelters designed for urban open spaces of a pronounced architectural quality are few. The well-known cases in Europe are pavilions, such as the 1987 Le Cylindre Sonore in Parc de la Villette in Paris (designed by Bernhard Leitner), the 2011 Serpentine Gallery Pavilion in Kensington Gardens (designed by Peter Zumthor), the 2012 Be Open Sound Portal (designed by Arup) at Trafalgar Square in London, and the 2012 Kampin Kappeli (Chapel of Silence, designed by K2S Architects) at Narinkka Square in Helsinki (7). Two of them are located in urban squares, two in urban parks; two of them were temporary architectural interventions in public space, and two are permanent. These pavilions were designed using a double shell 'house in a house' concept ensuring that the inner space is isolated from the surrounding soundscape and offers an opportunity for creating a designed and undisturbed one within.

Towards the criteria for the design of acoustic shelters, the fact that two different enclosed acoustic shelters were built in different spatial-functional types of an urban open space located in the same city offered an opportunity for their comparison.

## **3. METHODOLOGY**

Two temporary pavilions conceived as acoustic shelters were built in two different urban open spaces in London. Both were dismantled by the time of this research. In order to gain insight into the aural-context differences between the former immediate pavilion surroundings, by comparing the results of their general characterization, both quantitative (using software tools) and qualitative (using the listening tests) analyses of the monaural onsite measurements and recordings performed in October 2015 were conducted.

In addition, it was recognized that within the performed recordings exist coherent segments with a higher presence of prominent sound events and segments that are a bit calmer. Therefore, the analysis included the comparison of segments characterized by a different density of prominent sound events.

### **3.1 Site selection criteria**

Both sites were chosen for this comparison because the same soundscape design model was used in the same city within its historical center. This allowed for a pragmatic field research engaging several aspects: general enhancement of an urban open space, enhancement of an urban soundscape and enhancement of cultural heritage.

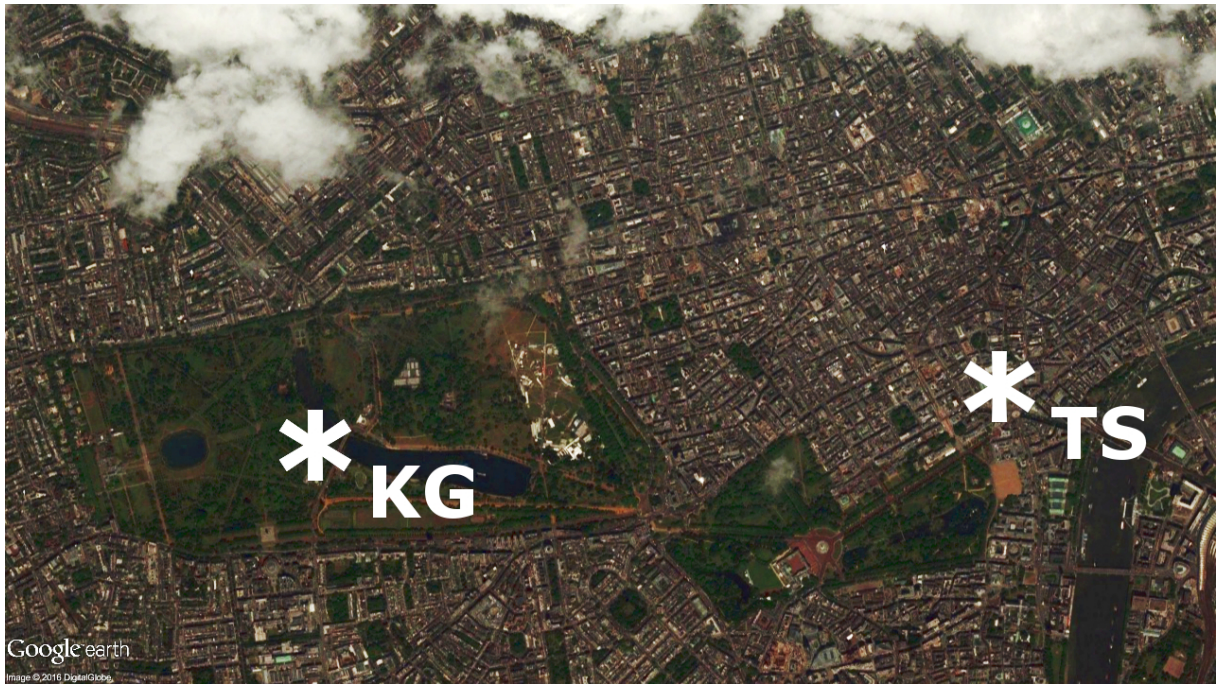


Figure 1 – Position of analyzed urban open spaces (\*‘KG’ is the position of the Serpentine Gallery in Kensington Gardens and \*‘TS’ is the position of Trafalgar Square) within the historical city center of London

### 3.2 Site description

Both sites are located on the northern bank of the River Thames, in the western part of Central London. Both are ‘famous London tourist sites’. They differ in their urban spatial-functional type, area size and the surrounding built structure.

Table 1 – Overview of analyzed urban open spaces and pavilions (Area sizes were defined using the Google Earth Pro application.)

Location	Area size in ha	Spatial-functional type	Sitting / resting area within the pavilion	Pavilion size in m <sup>2</sup>	Added designed sounds
Kensington Gardens	111	park	Yes	95	No
Trafalgar Square	1,25	square	/	60	Yes

Kensington Gardens are a large royal urban park which together with the Hyde Park forms an area of approximately 276 ha, separated by Lake Serpentine and/or West Carriage Drive.

The Serpentine Gallery is an art gallery located in the southeast part of the Gardens, next to one of the Garden’s main footpaths that leads from the Hyde Park Corner in the east across the West Carriage Drive to the Kensington Palace in the west. Since 2000, a new Serpentine Gallery Pavilion is being built every year in the Gallery’s forecourt by a different world-acclaimed architect who has not previously designed anything in London. These pavilions are annually open to the public in summer and early autumn.

In 2011 the Serpentine Gallery Pavilion was designed by the Swiss architect Peter Zumthor and the Dutch landscape architect Piet Oudlof.

One of the Zumthor’s main design intentions, following the idea of a garden within a garden, was to create an atrium which would offer a calm, isolated place for relaxation. Like all Serpentine Gallery Pavilions, it hosted the gallery café.

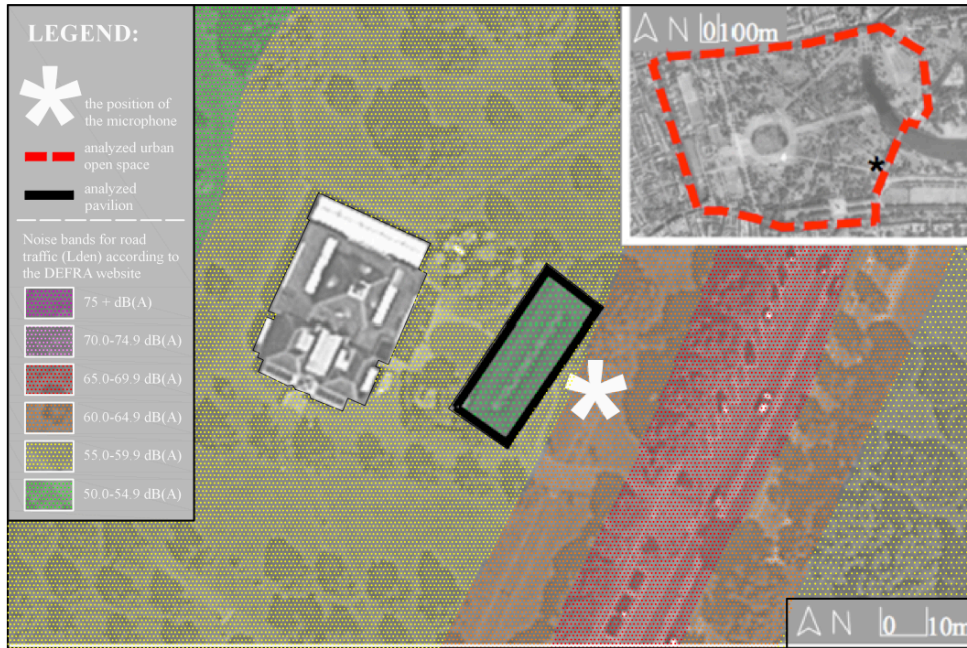


Figure 2 – Location of the pavilion in Kensington Gardens shown on a satellite picture captured using the Google Earth Pro application. The Serpentine Gallery can be seen west of the pavilion.

Trafalgar Square is one of the central squares in London. It is defined by the surrounding roads and monumental buildings such as the National Gallery, Canada House and South Africa House. Its central symmetrical composition is achieved by two water fountains flanking the axis with the Nelson's Column and the stairs leading to the main entrance of the National Gallery. The Square's topography follows the slope downwards the River Thames to the south and the view at the Big Ben tower on its left bank.

The Square was established in the early 19<sup>th</sup> century but traces its origin to the 14<sup>th</sup> century. Due to its significance in the city life, it is managed directly by the Mayor of London and London Assembly.



Figure 3 - Location at Trafalgar Square shown on a satellite picture captured using the Google Earth Pro application.

During the London Design Festival in 2012 a temporary pavilion named Be Open Sound Portal was erected at the Square. It was designed by the architectural firm Arup. Ned Cowe participated in the design process as the acoustics specialist. The design was commissioned by the London Design Festival and the Be Open Foundation. The pavilion featured an electroacoustic system conceived to enable reproduction of musical pieces within the pavilion. The pieces were composed by contemporary artists during one week in September 2012: Ivan Pavlov, Nathaniel Robin Mann, Jo Thomas, Tom Jenkinson and Jana Winderen.

### 3.3 Monaural recordings

Monaural recordings using an omnidirectional microphone were chosen because of being the most neutral regarding the spatial dynamic of sound sources. Binaural or even sound-field recordings are always biased by the orientation of the microphone – sound field recordings have clear frontal side. Monaural recordings are adequate sources for listening tests performed using headphones in situations where the spatial dynamics of sound sources is not considered relevant for the research.

Monaural recordings were made in October 2015 as follows: 1) at Kensington Gardens in front of the Serpentine Gallery on 18<sup>th</sup> of October, between 12:30 and 13:00; 2) at Trafalgar Square on 19<sup>th</sup> of October, between 12:00 and 12:30. Ten-minute intervals were recorded to ensure that relevant sound event circles, such as the traffic light exchange patterns, are captured.

The following equipment was used: 1) an omnidirectional pattern microphone, model Neumann KM 183; 2) a battery-powered portable preamplifier and an analog-to-digital signal converter device, model Apogee One for iPad & Mac; and 3) a tablet, model Apple iPad 3<sup>rd</sup> generation, as a recording device. Recordings were made in 24 bit / 44 kHz resolution using the Meta Recorder application. The microphone was placed on a microphone stand at the approximate height of an average listener's ears. The microphone and the recording equipment were calibrated so that the recording can be used for measuring sound pressure levels.

The microphone was positioned at the approximate location within a 10 m radius of the former pavilions location. The exact positions of the microphone in relation to the former pavilions are shown in Figures 2 and 3.

Recordings at the location in Kensington Gardens, as noticed by the authors, included the following sounds: motor traffic noise, brakes screeching, footsteps, passers-by talking and several people and children shouting while playing football in the Serpentine's Gallery courtyard. The latter was more pronounced in the first part of the recording (Figure 7). Recordings at the location at Trafalgar Square, as noticed by the authors, included: motor traffic noise, brakes screeching, emergency vehicles sirens, footsteps, passers-by talking and shouting, murmur of fountains and amplified music.

### 3.4 Visual experience

To enable the assessment of visual experience and the congruence between the visual and the aural, panoramic photos were taken at the locations during the recording. These photos were taken by a smartphone camera, model Apple iPhone 5, at the exact position of the microphone (Figures 2 and 3).



Figure 4 – Location in Kensington Gardens. The view to West Carriage Drive and the entrance to the forecourt of the Serpentine Gallery.



Figure 5 - Location on Trafalgar Square. From left to right: the Big Ben tower in the distance, Nelson's Column, western fountain, Canada House, National Gallery.

### 3.5 Listening tests

Listening tests were performed using a questionnaire based on the Swedish Soundscape-Quality Protocol in order to attain the general characterization of the experience of the two ambiances in question. The Swedish Soundscape-Quality Protocol is a soundscape assessment protocol developed by Axelsson, Nilsson and Berglund with the aim to provide a standardized soundscape assessment related to the type of the sound sources. It also includes an assessment of the congruence between the visual and the aural experience (8).

In total 20 listeners, 34 years old on average, attended the listening tests during May 2016. The majority of listeners were either students of architecture or architects, all living in Croatia. No listeners reported any hearing problems. The ratio of female to male respondents was 50:50. All listeners were familiar with the analyzed urban open spaces - 75 % have visited them a few times, 25 % have never visited them but were familiar with them. The tests were performed using a tablet device (Apple iPad 3<sup>rd</sup> generation), an audio interface (Apogee One for iPad & Mac) and a pair of headphones (Beyer Dynamic DT 990 PRO).

The listeners were given a pair of headphones and a questionnaire on a tablet device in a quiet indoor (classroom) environment. Audio excerpts were reproduced at the exact loudness within the questionnaire created using the Google Form application, using the YouTube video-sharing website.

## 4. RESULTS

### 4.1 The average sound pressure level, spectral composition and frequency of sonic events

The quantitative analysis included a standard average sound pressure level analysis using software tools and recordings containing the 94 dB calibration signal. It was separately performed for the whole recordings and for the four excerpts, used for the listening tests. The results of the sound pressure level analysis are shown in Table 2.

The maximum variation in the sound excerpts presented to the listeners was 8.3 dB. The listeners were presented with the non-filtered recordings.

According to the noise propagation map made available by the Department for Environment, Food and Rural Affairs – DEFRA (noise source: road traffic, Lden), used in Figures 2 and 3, the maximum possible variation between the two analyzed locations would be 15 dB. The measured sound pressure levels at both locations were 2-3 dB lower than the corresponding noise band.

The spectral composition and the frequency of sonic events in the 2-minute sound excerpts are shown in Figures 6–9. While spectral composition is rather similar in the recordings made at the same locations, the frequency of sonic events is different. Some specific sonic events, noticeable on the spectrograms, are described beneath each spectrogram.

The spectrograms of recordings made on Trafalgar Square reveal a much higher density of sound events and a lower fidelity of the soundscape, possibly also due to the murmur of the two water fountains. The previously mentioned spectrograms reveal seemingly much higher values of the low frequency noise than the ones recorded in Kensington Gardens.

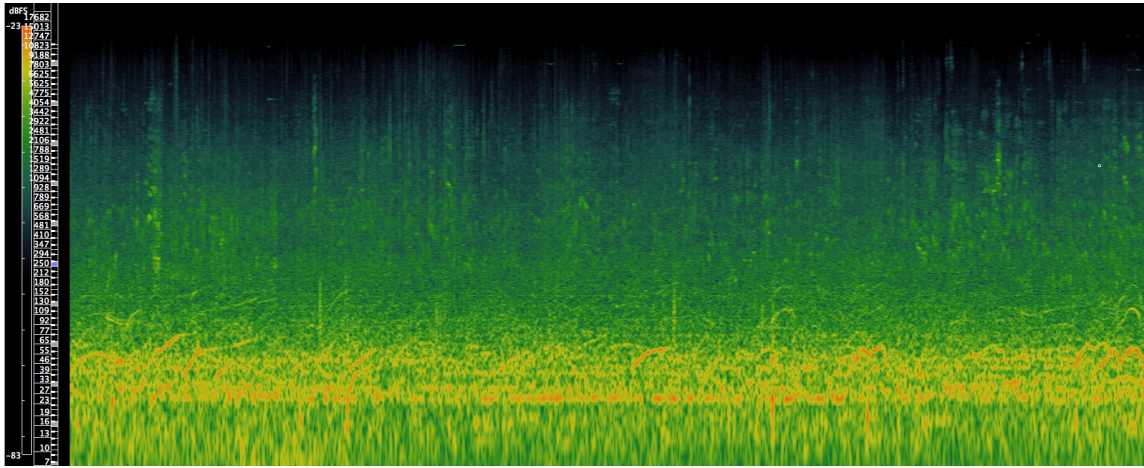


Figure 6 – Spectrogram of the first excerpt (KG 1) recorded at the location in Kensington Gardens.

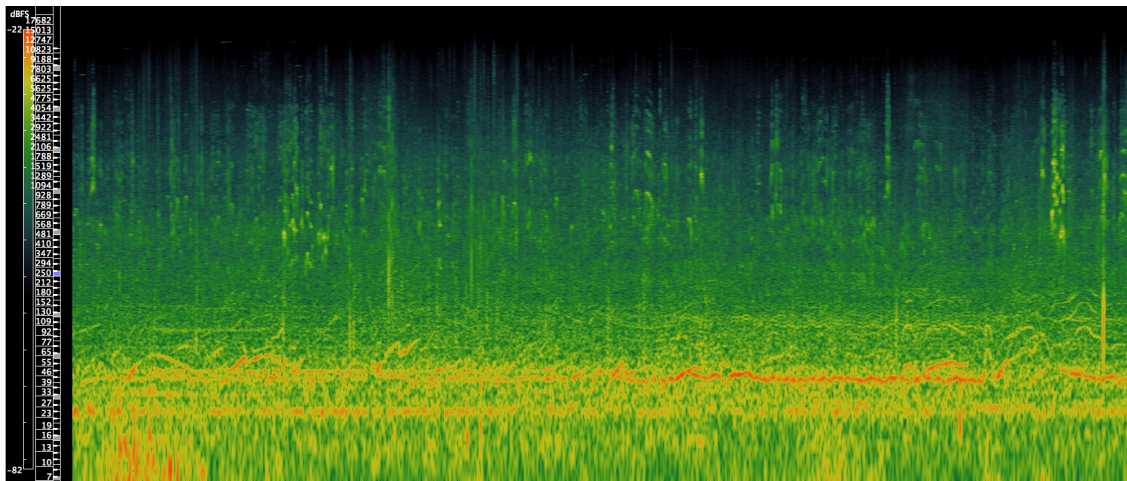


Figure 7 – Spectrogram of the second excerpt (KG 2) recorded at the location in Kensington Gardens. The second excerpt contains more prominent human sounds – sounds of several people and children shouting and laughing while playing football.

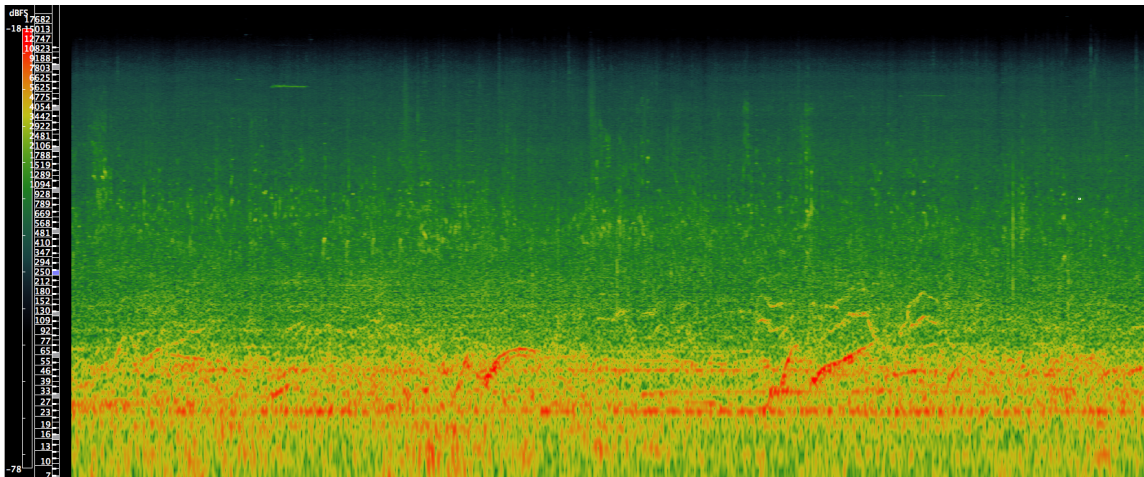


Figure 8 – Spectrogram of the first excerpt (TS 1) recorded at the location at Trafalgar Square

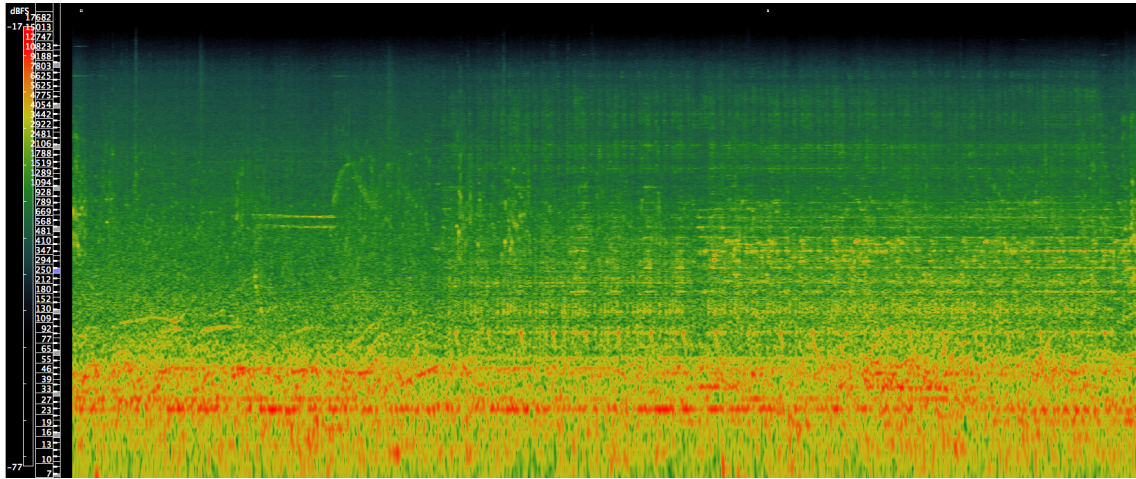


Figure 9 – Spectrogram of the second excerpt (TS 2) recorded at the location on Trafalgar Square. The second excerpt contains more prominent sounds – amplified musical content recognizable by the rhythmic repetitive pattern in the right two thirds of the spectrogram

The highest sound pressure level values at both locations can be seen in the area around 20 Hz and 45 Hz, produced by the motor traffic. In the last third of the second Trafalgar Square excerpt a rhythmic pattern represents amplified music starting as part of a street artist’s show. At the location in Kensington Gardens, such sound events are not visible.

The difference between the low frequencies (below 100 Hz) and the upper spectrum is visually distinguishable on spectrograms of both recordings, due to the significant difference in sound pressure levels. Within the area below 100 Hz prominent sounds are recognized by the red colour and the background ones by the yellow one, while in the upper spectrum the prominent sounds are green to yellow, and the background ones dark green to black due to lower sound pressure levels. The prominent sounds at the Kensington Gardens spectrograms are visually much more distinguishable.

Table 2 – Average sound pressure level per recording. The recordings are indexed as follows: 0 – the whole 10-minute range recordings, 1 – the 2-minute excerpt containing more frequent prominent sounds, 2 – the 2-minute excerpt containing more frequent prominent sounds

Location / recording number	Sound pressure level	
	dBZ	dBA
Kensington Gardens / 0	76.4	59.8
Kensington Gardens / 1	73.5	57.4
Kensington Gardens / 2	77.5	60.8
Trafalgar Square / 0	81.6	66.1
Trafalgar Square / 1	81.0	64.8
Trafalgar Square / 2	81.8	68.1

The dominant presence of the low frequency noise is also evident in Table 2 in the difference between the results calculated with and without the applied A-weight filter, which filters the lowest and the highest frequencies. The maximum difference between measurements with and without the filter was 16.2 dB, measured in the first excerpt of the recording on Trafalgar Square.



## 4.2 Survey results

Results of the Swedish Soundscape-Quality Protocol are in Table 3. The perceived dominant sound sources at the location in Kensington Gardens were human sounds. The perceived dominant sound sources at the location on Trafalgar Square were traffic noise and human sounds. In both locations natural sounds were the least audible.

A comparison of soundscape perception shows the soundscape at Trafalgar Square being clearly perceived as less uneventful, less calm, less monotonous and more chaotic than the one in the forecourt of the Serpentine Gallery. The soundscape of the Serpentine Gallery forecourt was perceived as more pleasant than the one at Trafalgar Square. Both soundscapes were assessed as equally eventful.

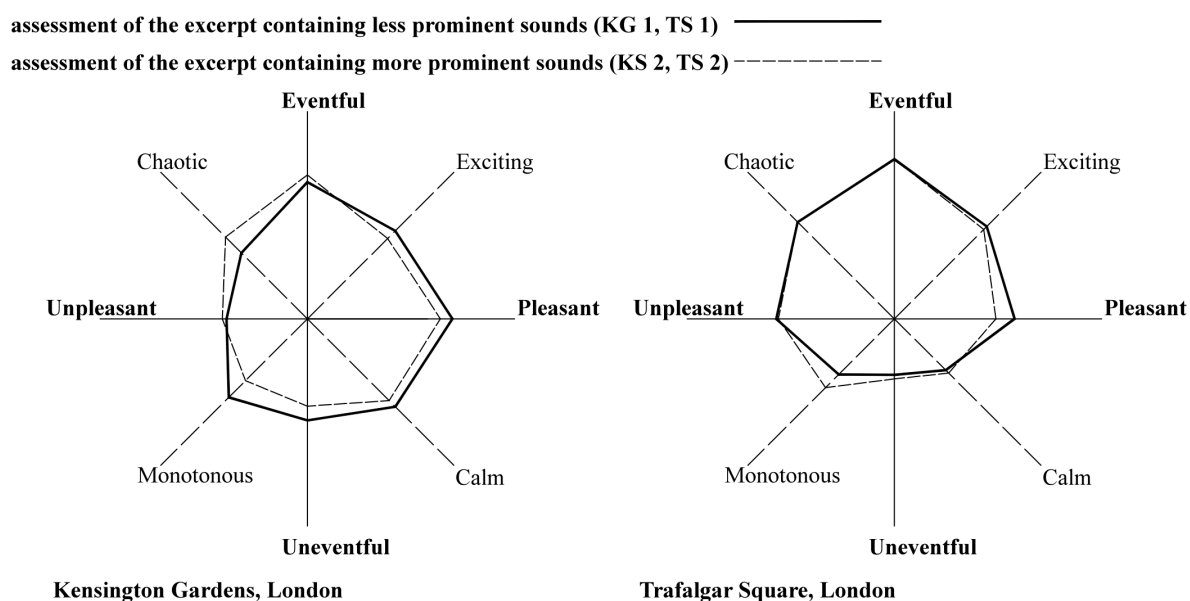
The question of pleasantness of soundscape excerpts recorded at Trafalgar Square showed controversial results – equally and strongly both pleasant and unpleasant answers (Figure 10).

Table 3 – Perceived dominance of sound source types / arithmetic means

Sound source type	Kensington	Kensington	Trafalgar Square _	Trafalgar Square
	Gardens _ 1	Gardens _ 2	1	_ 2
Traffic noise	2.75	2.58	4.16	3.42
Other noise	2.1	1.95	2.37	3.47
Human sounds	4.2	4.63	3.74	3.74
Natural sounds	2.05	1.71	1.84	1.47

Having in mind the specific model of an acoustic shelter, listeners were asked to express their need to change the analyzed ambiance for a much calmer one. They were offered the following options: 1) I am enjoying the current ambiance; 2) I do not care; 3) It would be hard for me to experience this ambiance during a longer period of time. This question revealed that Trafalgar Square was more convenient for a longer stay (50% enjoying it, 30% ambivalent), while the forecourt of the Serpentine Gallery caused more ambivalent reactions (40% enjoying, 35% ambivalent). Only the minority of listeners expressed a desire to change the ambiance of both locations.

Figure 10 – Arithmetic means of the soundscape perception values shown on a component model



## 5. FINAL REMARKS

The analyzed soundscape excerpts recorded in October 2015 at the Serpentine Gallery's forecourt

are characterized by lower average sound pressure level and a seemingly higher fidelity than those recorded in October 2015 at Trafalgar Square. Their perceptual quality is also different but both can be considered equally adequate for the corresponding urban open space. Zumthor's 'garden within a garden' was presumably contributing to a more enjoyable space rather than offering a shelter out of necessity.

Regarding the increase in frequency of prominent sonic events between the two excerpts from the same location, the comparison between the pairs of excerpts revealed the following: 1) the perceived increase in the dominance of human sounds and (unwanted) musical content (characterized as 'other noise' by some listeners); 2) perceived decrease in the presence of other sound source types; 3) increase in both measured sound pressure level values; 4) a slight shift towards the less pleasant soundscape characterization at both locations; 5) increase in the expressed need to change the analyzed ambiance for a calmer one.

Regarding the possible use of the research in urban planning and design, it can be concluded that since the analyzed acoustic shelters do not shield the entire urban space and are inherently intended for a specific use – designed experience of the enclosed space which supposes certain artistic value, they enhance the urban open space by offering a richer integral experience. One of their main values for the soundscape design would be the 'marketing one' – drawing attention to the importance of acoustic experience.

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