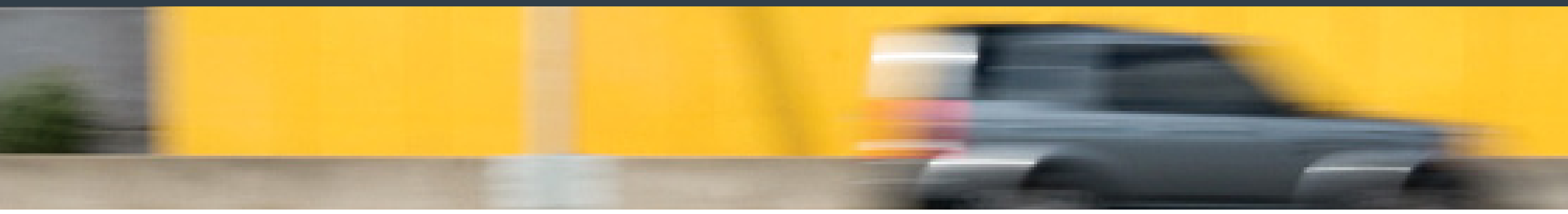
Research synopsis

Transurban

# RMIT Acoustic design innovations for managing motorway traffic noise by cancellation and transformation



Transurban awarded an Innovation Grant to RMIT University (RMIT) in 2016 to undertake research into managing motorway noise using active noise cancellation and transformation. The research, completed by RMIT was the first international example of applying ‘noise transformation’ using live electroacoustic technology in noise-affected environments to improve community perception of urban noise.

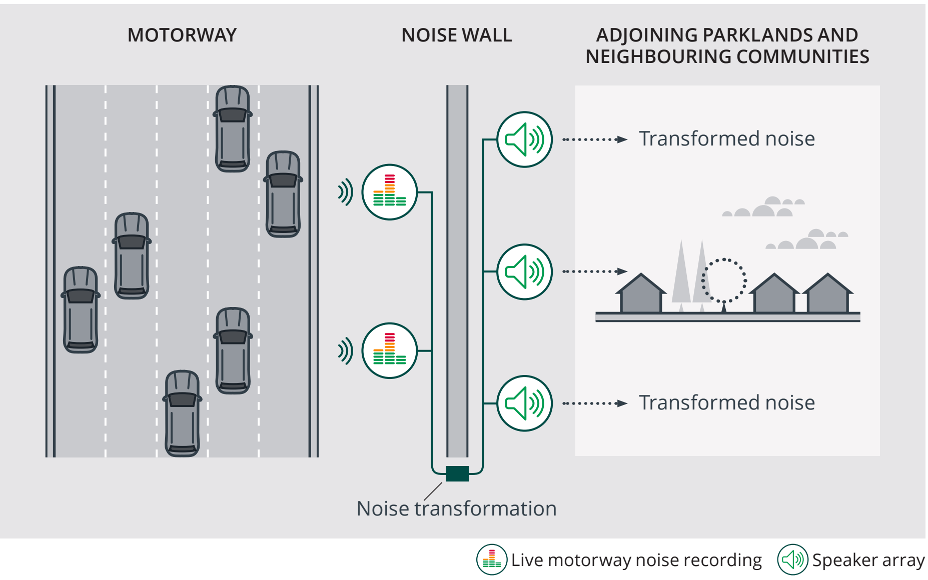
Urban environments are increasingly saturated with noise from a wide range of sources, including motorways. Improving the liveability of densely populated areas directly adjacent to motorways is a key part of our sustainability commitment to be good neighbours and deliver long lasting benefits to the environment and communities we serve.

Current methods of reducing motorway noise involve engineering approaches to reduce the noise emitted from vehicles and pavements or the installation of physical barriers or acoustic treatment to buildings to reduce noise propagation.

The RMIT research explored a new approach to managing propagated motorway noise. Through noise transformation, motorway noise is turned into a musical or aesthetic experience that is pleasing to the human ear. Rather than adopting a traditional engineering approach to quieten motorway noise, the transformation aspect of the research used noise as a source in musical composition, and recorded the response of neighbouring communities.

The research findings demonstrate the effective application of these alternative noise mitigation techniques can reduce the impact of motorway noise. Positive community response to demonstration sites established along Transurban’s CityLink (Victoria) and Hills M2 (New South Wales) motorways highlight the potential for such technologies to play a role in managing motorway noise. Used in existing or new motorway environments, such technologies could be applied to relieve noise impacts on sensitive receivers or in conjunction with urban design principles to activate public spaces.

The introduction of additional sound, albeit subtle, into the listening environment is contrary to current noise management policy, which historically has centred solely on sound reduction. The positive community response to the environments created during the trial however, shows the potential for renewed policy discussion and reform into how noise impacts and mitigation initiatives are measured.




**The full research report contains several key findings from the 12–month research project and provides an exciting new direction for improving human perceptions of motorway environments and the habitability of public spaces and backyards and balconies of private homes.**

TUCC155 0817

# Transurban Innovation Grant

Acoustic design innovations for managing motorway traffic noise by cancellation and transformation.

Report Authors:
Jordan Lacey, Sarah Pink,
Lawrence Harvey, Xiaojun Qiu, Shanti Sumartojo,
Sepei Zhao, Stephan Moore, Melisa Duque

**Submitted: 8th June, 2017**

Please read report alongside
companion website

click me

https://sites.rmit.edu.au/transurbaninnovationgrantrmit2016/

For site password please contact
Jordan Lacey
jordan.lacey@rmit.edu.au

---

## Research Team

### Project design and management

Dr Jordan Lacey

**Transformation Team**

Assoc Prof Lawrence Harvey
Dr Jordan Lacey
Dr Stephan Moore

**Cancellation team**

Prof Xiaojun Qiu
Sepei Zhao

**Ethnography Team**

Distinguished Prof Sarah Pink
Dr Shanti Sumartojo
Melissa Duque

**Studio Team**

Dr Ross McLeod
Assoc Prof Lawrence Harvey
Dr. Jordan Lacey

**Technical Team**

Simon Maisch
Ari Sharp
Timothy Percy

---

Contact
Jordan Lacey
Jordan.lacey@rmit.edu.au
0415661559

# Index

# Executive Summary

# Transurban Innovation Grant.

## Executive Summary

### Key Finding

Soundscape design of motorway environments presents new opportunities for existing and future infrastructure projects, which must contend with motorway noise issues. We have found that noise transformation and cancellation approaches integrated with targeted ethnographic assessments of community perceptions can add to existing noise management approaches, which aim to improve the quality of life for people living alongside motorway environments.

### Research overview

The research process has been primarily driven by the sound design team, who took the opportunity to test the possible application of noise transformation as a soundscape design tool. An acoustic engineering team were engaged to test the performance of a proprietary active noise cancellation (ANC) system, and the feasibility of combining ANC with noise transformation. And, an ethnography team provided insights into community responses to the noise transformation and cancellation field tests. Co-ordinating three disciplines to execute a single study was a challenging though highly rewarding task. The combined findings and recommendations present a rich array of thinking and potential approaches to understanding motorway noise and its management.

We have decided to provide each report as a standalone document. However, they should be read in unison to fully appreciate the scope of research that has been achieved. Research is presented in the following order:

1. The noise transformation report provides a detailed overview of the research process. It also contains the key findings, outcomes and implications of the noise transformation tests as revealed in laboratory and field conditions.

2. The cancellation report provides detailed feedback on the laboratory tests of the active noise cancellation (ANC) system. It also suggests future research that could lead to the successful application of the ANC system in outdoor motorway environments.

3. The ethnography report includes key insights and findings of community responses to motorway noise. Insights and findings are based on interviews executed in people's homes before the noise transformation and cancellation trials, and in a local parkland during the trials.

4. An urban design studio was formed towards the end of the field tests. The urban design studio presents three possible approaches to designing motorway parkland environments that apply noise transformation as a soundscape design tool.

## Motorway noise: a global issue

Given the increasing density of global urban populations, motorway noise management is an ongoing urban planning imperative. Motorway noise is both emitted and propagated. Reducing emitted motorway noise requires investment in technologies that reduce motor and rolling noise. Approaches include the production of more efficient engines, tyres and roads. These approaches might be thought of as 'pre-attenuation' noise management approaches. There are two primary approaches to managing propagated motorway noise: the installation of noise barriers, which reduce traffic noise by 5-10dB; and, acoustic design of adjacent homes and buildings, which, ideally, shield householders from external noise.

## A new approach to managing motorway noise

This research outlines a third approach to managing propagated motorway noise. Noise transformation focuses on human perception. It achieves this by turning motorway noise into a musical or aesthetic experience that is pleasing to the human ear. This research has focussed specifically on green spaces (parklands and backyards) that adjoin noise walls, and has worked closely with sensory ethnographers to ascertain which of the tested transformations are desirable to the public. Noise transformation can work independently or in combination with ANC systems, though further research is required to assess the performance of ANC in outdoor environments.

## Key disciplinary recommendations

Four key outcomes related to the three disciplinary approaches and the subsequent urban design studio are listed below. Each includes a summary, which have been drawn from the detailed disciplinary reports:

1. The test site installations prove that **noise transformation** can improve perceptions of motorway environments.

Community feedback proves that noise transformation is a soundscape design tool that can be applied by urban planners to improve human perceptions of motorway environments. The report states that future research should continue to refine the application of noise transformation as an industry method for improving the habitability of both public green spaces and the backyards and balconies of private homes.

2. While the proprietary active **noise cancellation** (ANC) system worked effectively in laboratory conditions, an upscaled system should improve its performance in motorway environments.

The existing active noise cancellation system provides an adequate sense in laboratory environments of its possible effects on motorway environments. Investment in a system with improved performance is required to test its possible impact on actual motorway noise environments. With mass production, the cost of such systems can be reduced significantly.

3. **Sensory ethnography** provides an important framework for understanding community perceptions of motorway noise

Sensory ethnography is an effective way to understand everyday attitudes to motorway sound environments. The ethnography report states that transformation has the potential to create new forms of well being. It recommends developing transformation technologies with an eye to how they might improve the everyday life experiences of citizens.

4. The provision of **urban design** proposals that improve community relationships with green spaces along noise walls.

A design studio explored the possibility of integrating noise transformation technologies into urban green spaces adjacent to motorways. Three typologies were discovered: corridor, wedge and field. Students developed a design calibrated to each typology, which are included in the final section of this report. These designs are considered as retrofits for existing motorway parklands, or as new approaches for future infrastructure projects.

# Transformation

## Noise Transformation

Left to right: Jordan Lacey, Stephan Moore, Lawrence Harvey

### Key Findings

**Transformations are transposable across environments with minimal changes required.** The primary change is amplitude adjustment. A total of three transformations from the original ten laboratory transformations were considered by the design team to work effectively in both environments. Detailed descriptions of the three transformations can be found below. These three transformations have been completed and are immediately transposable across multiple sites.

**Transformations considered by the research team to be operating at optimal capacity added only 1-3 dB to the overall sound pressure level.** A 1-3 dB addition to the acoustic environment is barely noticeable. However, onsite, the perceptual changes are significant. The environmental sounds can still be heard, which is why transformation should not be mistaken for masking. Masking attempts to block background sounds, whereas noise transformation requires background sounds to be heard in mixture with the transformed sounds to create new perceptual effects.

**By augmenting site-specific conditions more vibrant and eventful soundscapes are created.** Designs must respond to site-specific conditions, which is key to creating successful transformations. The very technique of capturing a live feed of background noise, and feeding that sound back into the immediate environment assures this outcome. This produces an augmentation of existing conditions that transforms annoying traffic sounds into more desirable soundscapes. We find a consistency here with recent lab-based studies that propose the terms 'vibrant' and 'eventful' as useful soundscape descriptors (Aletta 2016); that is, noise transformation is a practical method for turning annoying soundscapes into vibrant and eventful soundscapes.

**In principle, transformations can work in combination with the active noise cancellation system.** Transformations can work in combination with the active noise cancellation system, though at this stage, only in laboratory conditions (see cancellation report for details). The cancellation system can reduce the low-frequency component in laboratory conditions, leaving the residual mid-high frequencies to be targeted by transformation. Depending on the success of future field testing of the cancellation system, the transformations could be applied to a cancellation environment at any scale.

## Key Research Outcomes

**Noise transformation is an applicable approach to noise management of outdoor motorway environments.** Noise transformation is an applicable approach to noise management of outdoor motorway environments. This has been made clear to us from the community responses in Cremorne (see ethnography report) and Epping Community responses suggest that people found the transformed outdoor environments more pleasant and less anxiety-invoking. This supports the case for transformation as a noise management approach that improves perceptions of acoustic environments.

**This research is a proof-of-concept that noise transformation can work in real-world industry-based scenarios.** To date noise transformation has been a sound-art technique to create new and interesting listening environments both indoors and outdoors. The present research proves that the concept can be applied to motorway environments as a soundscape design tool, which creates more desirable listening environments.

**The grant has supported the creation of a deployable noise transformation system that can be applied to any public outdoor environment in all weather conditions.** The only additional item is a silent generator that can be easily hired. The present system is good for demonstration and research purposes; for instance, if we wanted to test new transformations or the applicability of existing transformations to new environments. See below (future implications) for discussions on costs of an upscaled system that could be applied across multiple sites.

## Key Research Implications

**Future research should include a range of sound designers to explore new possible transformation types.** Stephan Moore, lead sound designer, has created three transformations immediately deployable across motorway environments. As a creative research outcome, it is true to say that other designers might develop different transformations that could be equally as effective. Future research should look at hiring a number of sound designers (including Stephan Moore) to test new transformations in motorway environments. The more tested transformations the more diversity we can offer local communities and infrastructure projects, that wish to embed transformed motorway environments in local park lands. If the noise-transformation approach were rolled out across several sites, an expanded team would be required.

**Future installations would require investigations of designing for 24-hour and seasonal cycles, which accounts for changing traffic rhythms over the year.** The week-long transformation test sites revealed the variability in the daily and weekly flow of traffic. For instance, peak-hour traffic, which is slow moving, creates a different sonic profile to fast moving day time traffic. And, weekend traffic is sparser than weekday traffic. Future research should create systems with designs that are able to respond to the changing fluctuations of traffic patterns and even the changing of the seasons. Changes might include, shifting parameter settings to match the sounds captured by microphones, or the creation of different "moods" to match the seasons.

**Future research would require investigations of effective ways to integrate transformation technology into noise wall environments.** The end of this document includes urban design proposals from an MDIT-SIAL Master's studio. This is the first step towards investigating ways that transformation technologies could be embedded into noise wall environments. Future research would need to consider maintenance issues, vandal-proof infrastructures and power requirements. This stage of research would mean collaborating with an urban design team to look at solutions that embed technologies into desirable site-features such as high performance noise barriers and urban furniture. Costs for bigger system The present system could be scaled up... (Simon to research figures).

## Key Recommendation

Noise transformation is a noise management approach that can turn annoying soundscapes into vibrant and eventful soundscapes that are desirable to the public. Government and industry should embrace noise transformation as a soundscape tool for ameliorating noise annoyance in urban spaces, where noise propagation cannot be attenuated by acoustic engineering approaches. Future research should continue to refine the application of noise transformation as an industry method for improving the habitability of both public green spaces and the backyards/balconies of private homes.

## Audio Showcase Recordings

Details of the transformations are provided at the end of this report. The following two audio samples provide an overview of the three transformations, which were successfully tested at both test site installations. Recordings have been mastered to play back at equal volume levels. For best listening conditions, headphones are recommended.

| *Showcase Recording* | *Notes* | *Audio Sample* |
|---|---|---|
| Cremorne, Melbourne | Control, Microtonal, Pandiatonic, Relaxing Melodic | ▶ Listen 1 |
| Epping, Sydney | Control, Microtonal, Pandiatonic, Relaxing Melodic | ▶ Listen 2 |

# 1. Introduction

## 1.1 Design research

The school of Architecture and Design, RMIT University are pioneers in design research (Downton 2003). Design research differs from traditional forms of research. Rather than a hypothesis being formed then tested, knowledge is gained through the repetition of experiments (called iterations). In the case of this project there has been four iterations of experiments:

I. Plaza Tests: RMIT Design Hub
II. Laboratory Tests: SIAL Sound Studios and Design Archive
III. Initial Field Tests: Cremorne (Melbourne)
IV. Test-Site Installations: Cremorne (Melbourne) and Epping (Sydney)

Each iteration, described in detail below, led to further refinements until three ideal 'noise transformations' were discovered. This project demonstrates the growing relevance of design research, a still relatively obscure research methodology, to both identify and resolve industry and government problems. We state confidently that this is the first international example of the application of live electroacoustic technology to noise-afflicted environments to improve the perception of urban noise. Engineers were engaged to assess the possibile combination of ANC with transformation. See Part 2: Cancellation for a full description of the performance of the ANC system.

## 1.2 Soundscape design

Soundscape design is still a relatively unknown approach to noise management. Its central aim is to understand the impacts of urban sounds on social wellbeing (Schafer 1977, Davies 2010) and the capacity of design to improve city listening experiences. Typically, soundscape design approaches try to mask (Brown 2004) or attenuate urban noise. Recently acousticians and engineers have began to deploy the soundscape term as a means to foreground the importance of the perception of sound (Kang 2007, Alleta 2016). Lacey's (2016) book Sonic Rupture: a practice-led approach to urban soundscape design, proposed the concept of "noise transformation" as an artistic solution to resolve noise annoyance problems. Building on the noise transformation concept, this project takes a new turn in the field of soundscape design. By way of electroacoustic intervention, it attempts to transform negative perceptions of motorway sounds into positive perceptions.

## 1.3 Compositional influences

The sound design component of this research project was influenced by three composers. A brief description of each composer reveals approaches that have guided creative decisions made during the design process.

### 1.3.1 John Cage

John Cage was an early pioneer of the 20th Century avant-garde. For him, music was a means of accessing direct experience of the surrounding world. In 1952 he wrote "For living takes place each instant, and the instant is always changing. The wisest thing to do is to open one's ears immediately and hear a sound suddenly before one's thinking has a chance to turn it into something logical, abstract, or symbolical" (Nyman 1974). In his later years, visitors to his apartment above Manhattan's 6th Avenue would be invited to sit with him and listen to the sounds of the traffic coming in the window, which he considered beautiful. In our approach to Transformation, we follow a path we feel Cage would endorse — the sounds are not obscured but recontextualized, such that they appear featured and framed within a host of related sounds, taking on new meaning and new roles.

http://johncage.org/

### 1.3.2 Pauline Oliverios

Over several decades, the composer Pauline Oliveros developed a set of techniques and practices that she called "Deep Listening". The goal of these practices, in her words, was to cultivate "listening in every possible way to everything possible, to hear, no matter what one is doing" (Deep Listening Institute 2017). Stephan Moore, lead sound designer for this project, was a student of Oliveros and later became her collaborator and the main programmer of her interactive software for improvisation. Moore credits his work with Oliveros as fundamental to his conception and development of the transformations used in this project. In his own words: "In her performances, Pauline would begin by listening deeply, and then allow musical motivation to arise from what she found. Many of my transformation ideas arose not from a pre-existing hypothesis, but from intently listening to traffic and allowing those sounds to suggest the accompaniments that might best suit them".

http://paulineoliveros.us/

### 1.3.3 Brian Eno

Brian Eno pioneered ambient music, which he describes as 'an atmosphere, or a surrounding influence'. He states that 'ambient Music must be able to accommodate many levels of listening attention without enforcing one in particular; it must be as ignorable as it is interesting' (Eno 1978). This is consistent with the intentions of the research – to design sound environments that can be stimulating without inducing annoyance. His most well known album 'Music for Airports' was his attempt to produce an environmental music suitable for a specific typology – in this case, airports – that was 'intended to induce calm and a space to think' (ibid). The designed sounds of this project can be understood as ambient music designed for motorway parkland typologies, which is consistent with Eno's descriptions of environmental music. The main difference being that we are capturing a live feed of environmental noise in an effort to improve its listening qualities.

https://en.wikipedia.org/wiki/Brian_Eno

## 2. Site Selection

The selection of sites in Melbourne and Sydney proved to be a difficult process, which is often the way with research located in public environments. An original site found in Brunswick had to be abandoned due to projected Tulla widening construction works that would have affected the experimentations. We eventually settled on a site in Cremorne (see image 1). This site has excellent landscaping meaning the park was already well utilised, and nearby residents we could approach to participate in the study.

Image 1: East and West facing views of the Cremorne site

Several trips were taken to Sydney, which caused more difficulties. There were two reasons for this. Firstly, the topology of Sydney is often undulating and rocky making it difficult to locate the flat ground required to house the design equipment. Secondly, some suitable topologies had sound walls with less effective attenuation. This was particularly a problem for active noise cancellation, which required high-performing sound walls to carry out its own experimentations. The final site, a retaining basin located in Epping (Figure 2), was inaccessible to the public with minimal landscaping.

Image 2: The Epping retaining basin is large fenced area opposite Epping Heights Primary School

## 3. Field Recordings

High quality recordings of motorway environments were required to test initial transformations in the design hub plaza (see iteration I). Three recordings across three sites were collected (See Table 1), including two noise wall sites and a non-noise wall site. The non-noise wall site was recorded to provide an A/B comparison of the attenuating impacts of noise walls. The two noise wall sites were selected to hear the differences between peak-hour and non-peak hour conditions. The peak-hour recording (LD Johns Reserve, Brunswick W) was used for the laboratory tests (see iteration II).

| *Site* | *Address* | *Date and time* | *Leq (3m) Readings* | *Audio Sample* |
|---|---|---|---|---|
| 1 | LD Johns Reserve, McLean St, Brunswick W | 8 August 2016 8am | 55dB | Listen 3 Note: this audio was used for the labratory test |
| 2 | Reggio, Calabria Club, 476 Brunswick Road | 8 August 2016 10:30am | 76dB | No audio |
| 3 | Charles Evans Reserve, Cubbit St, Richmond | 24 August 10:45am | 60dB | No audio |

Table 1: Details of field recording sites

At sites 1 & 3 two xy pairs were set up 20m apart and 4m in from the soundwall (see Image 3). A Zoom mic (stereo) was placed in between. Site 2 configuration was an irregular arrangement due to difficult site conditions. The dB levels compared across the non-noise wall and noise wall sites suggest that the visited sound walls attenuate traffic sound by 15-20dB, an indication of high-performance barriers.

Image 3: Microphone placement at the Brunswick site

listen 3

The sound wall site with slow moving peak hour traffic (See Image 4) was 5-6 dB quieter than the sound wall site with free-flowing traffic. This immediately brought our attention to future research that would require a 24-hour design responding to changing traffic conditions (see key Implications above). This aim was unachievable for this project, but it

Image 4: Peak-hour traffic
conditions recorded at Cremorne

## 4. Design Iteration I: Plaza Tests

Motorway parkland soundscape recordings were played back in the SIAL Sound Studio's POD and initial designs were completed using Ableton Live. The applied technique was multiband filtering, in which four different frequency bands were transformed using multiple effects that could be individually switched on and off. Interestingly, this was the first indication of the potential of interactivity to be incorporated into the design. These transformations were then tested in the plaza of the Design Hub.

Unfortunately, we didn't organise audio recordings of this test. We were focussed on the technique of capturing live audio at this stage. This was a proof-of-concept phase (see key outcomes above) in which both the possibility of capturing a live feed of traffic, and the relationality that existed between the traffic sound and the transformation zone were made apparent. It was immediately clear that the technique was pleasurable to the human ear. This was the first of many moments in which researchers witnessed groups of people settling into the new acoustic environments, and anecdotally reporting positive listening experiences.

The tests included four HKs networked to a computer, with two Sennheiser microphones attached to the scaffolding facing Victoria Street. The cabling was approx. a 30m run (see Image 5). We used the same equipment in the field tests (see iteration IV).

Image 5: Microphones were mounted to
the scaffolding which fed live traffic sound
into a transformation zone.

# 5. Design Iteration II: Laboratory tests

## 5.1 The combination system

Now that we had the required recordings, equipment and proof-of concept, iteration II tested these ideas in laboratory conditions. This was the first time the designers worked with the engineers towards the creation of a combination system, and towards the creation of transformations that would be subsequently tested in the field. Image 6 shows the final set-up of the combination system.

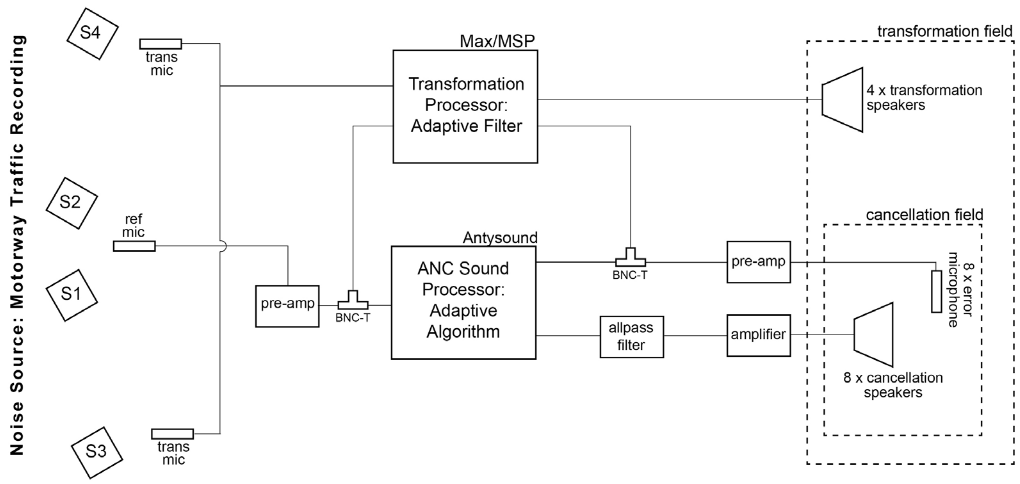
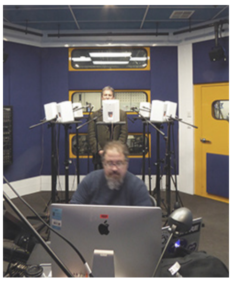



Image 6: technical diagram of the combination system

The combination system was played back in two separate spaces (Image 7) – The POD and the Archive space. It was noted in both spaces that the ANC equipment is able to attenuate low frequency sounds (100-300 KHz) by 5 dB, however the reduction could not be perceived in the archive space due to the highly reflective surfaces of this space amplifying sounds in the frequency spectrum above 300Hz. However, we were able to achieve excellent listening outcomes in the POD with the noise cancellation system which the designers could then interact with to create combination environments. During laboratory testing we developed ten independent transformations that can work both with and without cancellation. Three of these transformations were found to work in both test-site installations (see iteration IV). For detailing information regarding the performance of the ANC system in labratory conditions see the cancellation report.



The Pod

The Archive Space

Image 7: The two testing spaces

## 5.2 Uncoupling the system

An interesting outcome for the research team was discovering the challenges of combining the two different methodologies practiced by the engineering team and the design team. The engineering team reported a successful reduction in noise level measured with SPL equipment that was only sometimes perceivable to the human ear. For the design team, human perception of changes to the sound environment is critical if the combination system (Image 6) is to function effectively as a soundscape design tool. We predicted, based on our laboratory tests, that the ANC system will have no perceivable effects in the field, which turned out to be true.

Given our prediction that there would be no perceivable impact of the ANC system, we decided to test an uncoupled system in the field (see figures 8 and 9). For the final day of our laboratory tests, we explored this idea. We considered that cancellation might be better focused on a home environment (indoors or backyards). We began testing this idea in the POD by installing a cancellation system in an open doorway (see cancellation report for further details). This considers the possibility of low frequency cancellation in home environments where doors and windows are left open (Figure 8). Although this was not pursued in future iterations, we suggest that any future combination testing might explore this approach.

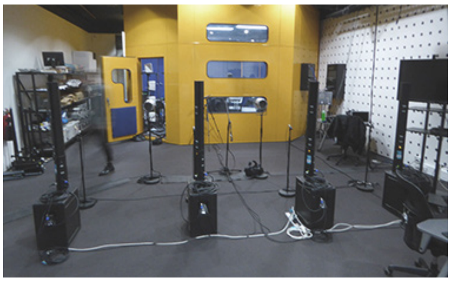


Figure 8: Cancellation in Open Doorway

Figure 9: Testing transformation in open environment. Note cancellation equipment in open doorway.

We also began to consider the idea of transformation being exclusively focused on motorway parklands to improve livability and walkability around urban motorway environments. This idea is based on research that suggests motorway noise creates fatigue and lethargy leading to negative health impacts caused by a lack of exercise (Foraster 2016). The research team refocussed its efforts on making motorway parklands habitable by creating transformed soundscapes (see Figure 9). This idea was maintained throughout the research and informed the student-led motorway parkland urban design proposals included at the back of this report.

## 6. Design Iteration III: Initial site tests

Before proceeding to the final test sites, we decided to test the uncoupled cancellation and transformation systems onsite in Cremorne (see Figure 10). The main purpose of this test was to account for any new equipment we would require for the final test sites to create our fully deployable soundscape design system (see key outcome above) and also to give ourselves an initial sense of the performance of both systems. It was immediately clear that combination would not work outside of laboratory conditions as the cancellation system produced no perceivable effect in the parkland environment. However, we did discover in these tests that the transformations developed in the studio were able to interact effectively with the motorway sounds.

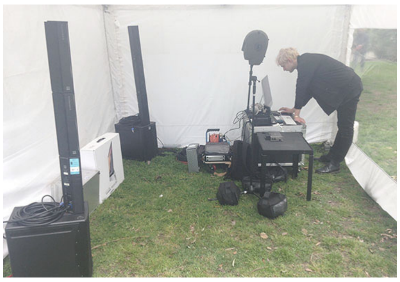


Figure 10: Cancellation and transformation were separately tested over two days. All ten laboratory transformations were tested.

We used two HK speakers only. It was raining on the day, but we felt this did not impact the listening experience. Similarly, to the plaza test in the Design Hub there was a pleasing consistency between the traffic sounds and transformed sounds which lends itself positively to a soundscape design approach. We tested all ten transformations developed in the laboratory tests. At this stage they acted well as sketches. It was clear that during the final test site installations they would require onsite 'tuning'.

Final decisions were made about additional equipment to complete a fully deployable noise transformation system. These included:

- steel plated studio mic stands to reduce surface area of ANC system
- solution for connecting ANC speaker joins with mic stands
- purchase more sandbags to secure mic stands
- purchase ratchets to avoid ANC system pack down each day
- a Coates silent generator was successful. To hire for following tests.
- purchase separate 3x3m marque for cancellation and transformation
- complete health & safety equipment purchasing to avoid trip hazards and electrocution
- toilet hire necessary
- hire food truck to arrive each day over lunch.

# 7. Design Iteration IV: Final test sites

There were two installation periods in which the laboratory derived transformations were tuned to real world conditions. See 'site selection' above for images of final sites. The Cremorne (Melbourne) installation took place from the 20 – 26 February 2017 and the Epping (Sydney) installation took place from 16 – 19 March 2017. Technical set-up for generating transformation sounds at both sites included:

- A mac desktop computer running Max/MSP
- Motu soundcard
- Four HK speakers with weather proof covers
- Two Sennheiser microphones on stands
- A silent generator
- Cable matting and electrical safety connectors

## 7.1 Melbourne test site installation

Figure 11: The Cremorne installation site. Photos in left column taken on industry day. Photos in right column of onsite transformation.

The Cremorne installation (see Figure 11) took place in excellent weather conditions. Each day was still, warm and rainless. A hired Pantech truck was driven onsite each day for seven days, and two installation tents – one for cancellation and one for transformation – were set up by three technical officers. See figure 12 for technical set-up.

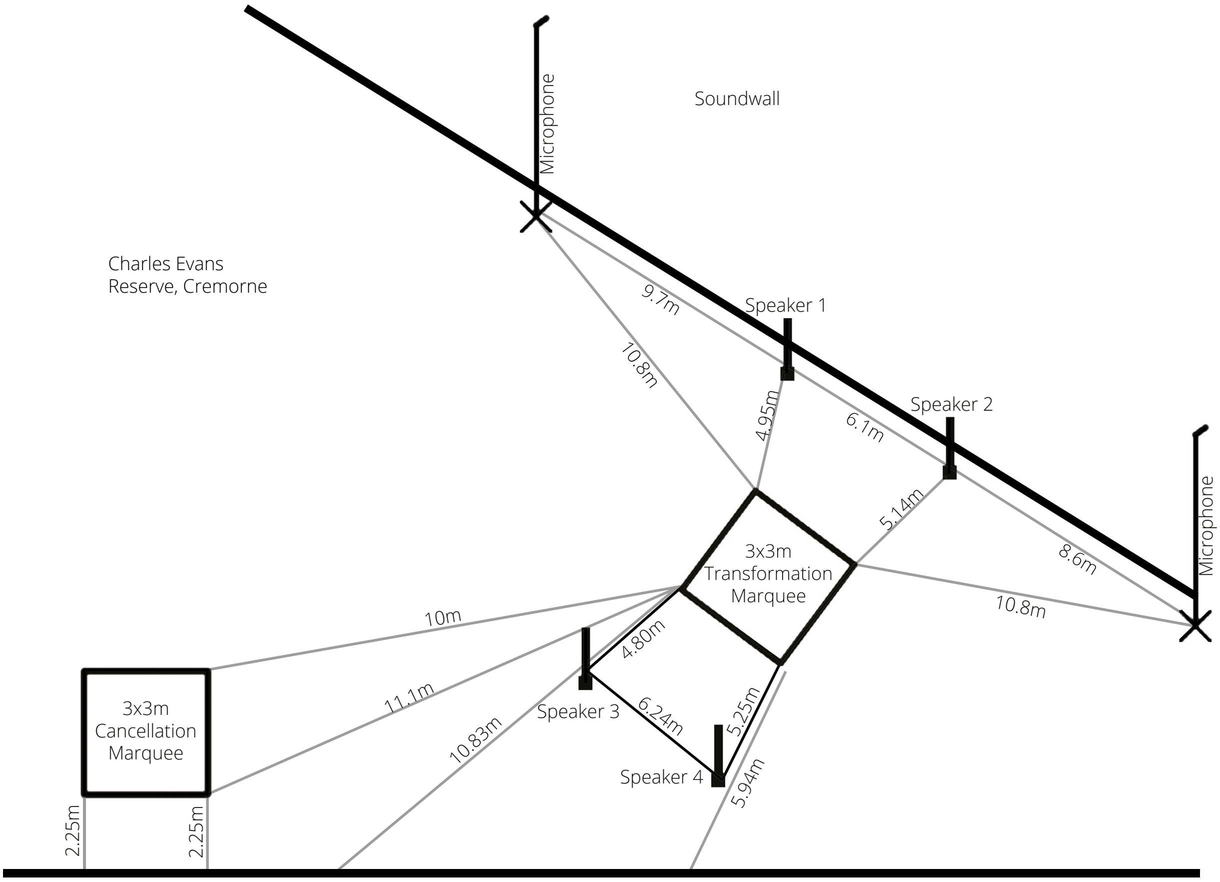



Figure 12: diagram of spatial arrangement of Cremorne technical set-up

Microphones were located such that the listener was placed in the middle of the stereo field of captured sound. And, the quadraphonic speaker arrangement was located to place the listener in the middle of the field of played back sounds. The strategic advantage of this configuration is to centre the listener in both the live sound capturing and playback technology. However, after our Sydney playback we realised it wasn't necessary to place the listener at the centre of the microphone array. Microphone placement provided little strategic listening advantage insofar as the perception of the transformations. Four of the ten laboratory transformations were finalised and tuned for weekend playback to the community, which is detailed in the ethnography report.

The following table includes the name of the four transformations and the order in which they were played back to the community. It also shows the total increase in dB to compared with the original sound environment. Each transformation is represented by a 1m audio sample. Average SPL measurements were taken with a B&K SPL meter over 3-minutes. Recordings were taken with a binaural head mounted with windsock. Recordings have been mastered to play back at equal volume levels. For best listening conditions, headphones are recommended. As the ANC system had no perceivable impact on the traffic sound, a demonstration was set up so that the community could hear its effects. Listen 9 provides a field recording.

| *Recording Name* | *dB Level (Leq3m)* | *Audio Sample* |
|---|---|---|
| Environmental Average | 59.5dB | Listen 4 |
| Relaxing Melodic | 62.2dB | Listen 5 |
| Microtonal | 61.9dB | Listen 6 |
| Seaside | 59.8dB | Listen 7 |
| Pan-diatonic | 60.2dB | Listen 8 |
| Cancellation Demonstration | - | Listen 9 |

Table 2: Field recordings of Cremorne test site installation transformations

## 7.2 Sydney test site installation

Figure 13: Collage of Epping site. Note the wet conditions and retaining basin.

The field conditions in Sydney were considerably more difficult due to high rainfall and windy conditions. The extensive weather proofing of the soundscape design equipment was well justified at this time. A downpour had no impact on the hi-fi equipment. The weather conditions had no impact on the transformations, with a clear relationship between traffic sounds and playback sounds still being achieved. However, the Epping site did contain a large retaining basin with running water that made a loud background noise during playback (see figure 13). This made one of our transformations, Seaside, less desirable as it seemed to clash with the background sound of the water flow. However, the wet weather conditions provided three new insights:

1. Firstly, we discovered a new transformation – the sound of rain hitting a plastic cover on the microphones (listen 14). It was a pleasing moment because it revealed that transformations could be creatively applied to other site-specific sounds besides traffic noise.
2. It revealed how electroacoustic transformation might combine with water features to produce new soundscapes. In effect, the water fountains would mask the low frequency bands of the traffic while the transformation system would recreate listening experiences of the residual sound field. Thus water features would play the same role as the ANC system.
3. A group of students joined the research team to investigate ways in which they might imagine redesigning such spaces to increase community use (see Fig 13). The resulting urban design ideas can be found at the back of the report. Both of the first two insights, related to the wet weather and presence of the retaining basin, were influential on the student’s thinking.

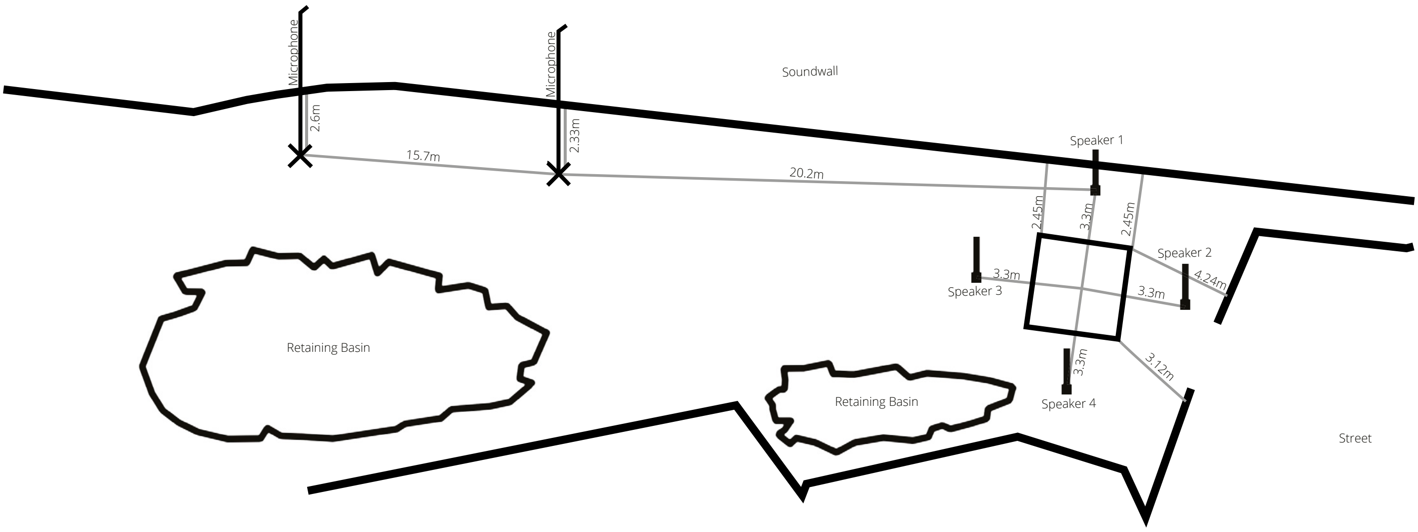



Figure 14: diagram of spatial arrangement of Epping technical set-up

Due to space restrictions, we had to place the generator on the right side of the installation and the microphones to the left side (see figure 14) so that the sound of the generator would not be fed into the microphones. The new microphone placement taught us that having the listener in between the stereo arrangement of the microphones is unimportant for the successful perceptual effect of transformation to occur. This suggests that listening conditions are not adversely affected by microphone placement as long as the microphones can successfully pick up traffic sound in their location.

The following table includes the name of the three final transformations that were successful on-site. Seaside was not successful in this environment due to its clash with existing water sounds. It also shows the total increase in dB of transformed environments compared with the environmental average. Each transformation is accompanied by a 1m audio sample. Average SPL measurement were taken with a B&K SPL meter over 3-minutes. Recordings were taken with a binaural head mounted with windsock. Recordings have been mastered to play back at equal volume levels. For best listening conditions, headphones are recommended. Due to our confirmation that the ANC system did not work in field conditions, we did not test cancellation at the Epping site.

| *Recording Name* | *dB Level (Leq3m)* | *Audio Sample* |
|---|---|---|
| Environmental Average | 53.2dB | Listen 10 |
| Pan-diatonic | 53.7dB | Listen 11 |
| Microtonal | 54.4dB | Listen 12 |
| Relaxing Melodic | 53.7dB | Listen 13 |
| Rain | - | Listen 14 |

## 7.2.1 Community feedback

There was no ethnography in the Sydney iteration of this research. However, without solicitation four teachers from Epping Heights Primary school and two local residents visited the installations. Three in total agreed to provide their thoughts by email which can be found below. We believe, in combination with the ethnography report, that this further emphasises how successful the transformations were and the desire of the community to live with such transformations. The emails are provided here without editing. They should be considered a further reinforcement of the ethnography discoveries.

Craig Eggleton: Epping Heights Primary School Teacher

Thank you for allowing us to observe your research last Saturday. I found the project intriguing to say the least, and fascinating that anyone had ever thought to counter the constant drone of traffic with audio technology. As a resident of a nearby suburb to the school, who lives not too far from the motorway, I need to state that I would find the alternative sounds offered by your equipment much more inviting than the sound of passing vehicles.

*How did it make the space feel?*
I think the alternative sounds made the space feel more inviting.

*Could you imagine if it were in the space permanently?*
I could. With a little landscaping, some benches to sit upon and the removal of the tall fences capped with barbed-wire, I can picture a tranquil area for people to relax and read a book.

*Could you imagine what it would be like having it in a part of the school grounds permanently?*
Absolutely. I immediately saw the educational value in having such research take place on school grounds. I also saw the educational value of having such a project permanently set up in the playground. The possibilities are limitless, but my immediate thoughts turned to an outdoor classroom with a surrounding garden which could be used alternatively for

students wanting a little quiet time away from loud play during recess and lunch.
I think the whole concept is brilliant and I really would like to see such an idea implemented into areas with high traffic, especially places like schools, elderly residential areas and parks. My hope is that I'll see this in action in the near future and that it will become the "norm" when planning infrastructure such as high traffic zones around residential areas.

Melissa Cairn: Epping Heights Primary School Teacher

*How did it make the space feel?*
The space made me feel much calmer and also excited at the thought that your team may have come up with a way for us to live in harmony with these noises rather than always looking for ways we can move away from or block out the sound. Traffic noise such as that on the freeway can become such a part of our lives that we almost get used to it but I think we (and me in particular) underestimate the way the additional noises can add to our stress and anxiety levels as though those noises are constantly competing with our thoughts and our feelings of calm.

*Could you imagine if it were in the space permanently?*
I would love to see this "sound garden' being made into a permanent space. I love the idea that you are not fighting against the inevitable noise pollution of our modern cities but instead finding a way in which we can live with it more harmoniously. I particularly liked the way you have designed it so that if there is no traffic then there is no noise, therefore allowing moments of real peace and quiet where possible. In other times though the music and sounds you have created make being around the noise more bearable and less jarring.

*Could you imagine what it would be like having it in a part of the school grounds permanently?*
I would be super excited to see this a part of our school grounds. There could be so many wonderful opportunities here. The space would of course be a more attractive and usable space for learning activities but it would also be such wonderful role modelling for our students. Imagine having a real life example where science and creativity worked together to partially solve a modern day problem such as noise pollution? In a world where we are asking our students to be innovative, having an example to refer to regularly, and perhaps scientists and sounds engineers to talk to every so often, would be just wonderful for our students.

Thank you again for your time on the day and explaining everything so well I have talked about that project quite a lot to my family and friends and feel inspired by what you are doing. I hope all goes well for the project.

Eden Taylor*:* local resident

*How did it make the space feel?*
I found the installation really interesting. With the set up that you had there that day, it transformed a "dead" space to a space that was quite pleasant to be in. Once I understood the concept, it started to create a positive awareness for me of the sounds around us, in particular, the raindrops. It was also very interesting that the different filters being used created quite different feels - there were some that personally I found more pleasant than others.

*Could you imagine if it were in the space permanently?*
If this was in the space, or my backyard, permanently, I think it would have a real positive impact on the environment. A lot of the sounds I heard on the day somehow had a more natural sound than the traffic noise as well as having a soothing effect. One thing I do wonder is what control could be had in terms of the different filters used and whether they could be switched on and off.

### Community Feedback Summary

Though a small sample, in combination with the ethnography results, and our own anecdotal conversations during the various sound design iterations, the premise of noise transformation appears to be one that the community is ready to embrace. The words “peaceful”, “relaxing” and “less anxious” kept emerging, as they do in these interview fragments. While it may seem counter-intuitive at first to be adding dB to the environment, it is clear that targeting perceptual responses can have a real benefit to the community. We are confident that if industry and governments embrace the noise management approach of noise transformation that it will ameliorate the impact of noise pollution in those spaces where full attenuation is impossible.

## 8. Sound Design Details

### 8.1 The transformation system

We designed a system of microphones and speakers with a computer at the centre running sound analysis and processing software written in the Max environment that was capable of interfacing with other common tools, such as Ableton Live and the GRM Tools suite of plug-ins. The Transformation System’s microphones collect environmental sound directly, and pass that sound to the processor where it can be analysed for its amplitude envelope and spectral content. The sound is then either passed through a set of transformational processes, or new sounds are produced in response to the analysis results. We refer to a set of these processes as a “Transformation”, a process that combines music composition, algorithmic design (coding), and audio engineering.

The sound resulting from the Transformation is then passed out to a multi-channel speaker system which distributes it back into the soundscape according to the location of the system’s microphones. Speakers must, necessarily, be positioned such that they are behind the system’s microphones, pointing away from them. (The microphones, in turn, should have a polar pattern that rejects sound from behind, such as a cardioid pattern.) In our case, one speaker was used for every microphone, though other arrangements are possible. Transformation Systems are easily scalable when the ratio and relative placement of microphones to speakers can be fixed.

### 8.2 Design considerations of the transformations

The areas adjacent to roadways are noisy places, and the Transformation System, by definition, will introduce even more sonic energy into these soundscapes. Therefore, care must be taken to ensure that the layer of added sound is applied as judiciously and sparingly as possible, so as not to create a nuisance greater than the one we intend to mitigate. The realization of this constraint has guided us towards designing Transformations that are:

- closely tied to the actual environmental sounds, so that the contour of those sounds is reflected in the Transformation and the two layers of sound merge in the listener’s perception.
- dynamically constructed, capable of responding to variations in the average amplitude and spectral content of the soundscape as it passes from rush hour traffic levels to quieter times of day.

- primarily composed of higher-frequency sounds, so as not to compound the build-up of low-frequency noise that is characteristic to these soundscapes.

We have experimented with Transformations that have dynamically-activated layers of activity, or that sometimes fall silent or have periods of sparseness that occur in either direct or inverse relationship to the behaviour of the soundscape. The transformations described below comply with these design principles variously, as these principles were not pre-determined, but articulated in conjunction with the Transformation design process.

## 8.3 The four transformations tested with community members

Each of the four tranformations are linked with the corresponding community responses reported in the enthography report

### Transformation 1: Relaxing Melodic

Listen 5

Incoming audio streams are each fed through resonant bandpass filters. The tuning of each filter changes over time according to an algorithmic scheme that determines melodic arc and rhythm. In contrast to the "choir" transformation, an equal-temperament tuning scheme is used, there are 16 individual voices, and each voice moves independently. The effect is that of a number of meandering melodic voices whose timbre shifts according to what is happening in the soundscape. The stream feeding each individual voice is delayed by anywhere from 1 to 8 seconds, allowing each voice to be more differentiated and creating a more layered effect overall. This also allows major events in the soundscape to play out spatially over the course of several seconds, endowing them with greater significance while smoothing out their impact.

### Transformation 2: Microtonal soundmass

Listen 6

A pitch-detection process is applied to the incoming audio signals, and prominent pitches are extracted. Because of the nature of the soundscape, these pitches may or may not be evident to the naked ear. The pitches are quantized onto a chromatic grid and then used to tune one of ten triangle wave oscillators. These oscillators, when triggered by an incoming detected pitch, execute a pre-determined 1-second envelope with a sharp attack and decay. The triggering and re-triggering of sounds is controlled by a sensitivity algorithm, where triggering a sound also decreases sensitivity to incoming pitches. The sensitivity returns over time, such that a single oscillator will re-trigger after a set period if nothing changes, but will re-trigger more quickly if the intensity of the detected pitch increases, and more slowly if the intensity decreases. These sounds are then subject to a long, cavernous reverberation that locates them within, or even beyond, the present soundscape. The timbre of the triangle wave has a video game-like quality, which informs the feel of the Transformation experience. The oscillators use a sine wave shape, the envelope has a faster attack, and the pitches are left raw (unquantized). The lack of overtones gives the notes produced by this transformation a softer presence, and the lack of pitch quantization makes the system feel closely connected to the soundscape's contents.

### Transformation 3: Seaside

Listen 7

This Transformation applies a resonant highpass filter to the incoming audio, with a moving parameter that simulate the sounds of a roaring surf in the mid-distance. The intention was to make the traffic sound more organic and "natural" without fundamentally changing it. The cutoff frequency, resonance (Q), overall level and spatialization of each of the Transformation's four layers of sound undergo constant random shifting within a constrained band of possibilities.

### Transformation 4: Pan-diatonic soundmass

Listen 8

A pitch-detection process is applied to the incoming audio signals, and prominent pitches are extracted. Because of the nature of the soundscape, these pitches may or may not be evident to the naked ear. The pitches are quantized onto a chromatic grid and then used to tune one of ten triangle wave oscillators. These oscillators, when triggered by an incoming detected pitch, execute a pre-determined 1-second envelope with a sharp attack and decay. The triggering and re-triggering of sounds is controlled by a sensitivity algorithm, where triggering a sound also decreases sensitivity to incoming pitches. The sensitivity returns over time, such that a single oscillator will re-trigger after a set period if nothing changes, but will re-trigger more quickly if the intensity of the detected pitch increases, and more slowly if the intensity decreases. These sounds are then subject to a long, cavernous reverberation that locates them within, or even beyond, the present soundscape. The timbre of the triangle wave has a video game-like quality, which informs the feel of the Transformation experience. The oscillators use a square wave shape, the envelope has a slower attack and is softer in character, and the pitches are quantized to notes that are members of the key of C Major. The tonality of these pitches as they aggregate in the reverberation give an "ambient" and uplifting feel to the Transformation, while still feeling connected to the soundscape.

## 8.4 The combination filter

Part of our experimental process involved using these Transformations in combination with the Active Noise Cancelling system. In those cases, we added another layer of audio processing pre-Transformation, which we called the "Combination Filter". The idea was that, since so many of the Transformation act upon the environmental sound, we wanted to be sure not to reintroduce frequencies that the ANC system was removing. The strategy was to analyze the environmental sound both pre- and post-ANC processing, and to compare these analyses to determine what effect the system was having. This ongoing comparison formed the basis for a dynamic FFT-based filter. This Combination filter was then applied to all incoming signals, to ensure that Transformations reflected the ANC system's influence. The filter was not applied in the field as the ANC system created no perceivable effects outside of labratory conditions.

# References

Aletta, F. and J.Kang (2016) 'Soundscape descriptors and a conceptual framework for developing predictive soundscape models', Landscape and Urban Planning, 149: 65 – 74.

Brown, L., and A. Muhar (2004), 'An Approach to the Acoustic Design of Outdoor Space', Journal of Environmental Planning and Management, 47 (6): 827–42.

Davies, W. J., M. Adams, N. Bruce, M. Marselle, R. Cain, P. A. Jennings, J. Poxon, A. Carlyle, P. Cusack, D. Hall, A. Irwin, K. Hume and C. J. Plack (2010), 'The positive soundscape project: A synthesis of results from many disciplines', Proceedings of 38th International Congress and Exposition on Noise Control Engineering, Ottawa, ON, Canada, 23–26 August 2009. Published in: Proceedings of the 38th International Congress and Exposition on Noise Control Engineering, 1: 663–72.

Deep Listening Institute (2017) 'Mission Statement: So What is Deep Listening?'. Retrieved from: http://deeplistening.org/site/content/about

Downton, P. (2003) Design Research, RMIT University Press: Melbourne

Eno, B. (1978) 'Music for Airports PVC 7908 (AMB 001)' liner notes, Polydor Records.

Foraster, M., I. Eze, D. Vienneau, M. Brink, C. Cajochen, S. Caviezel, H.Hertier, E.Schaffner, C. Schindler, M. Wanner, J.Wunderli, M. Roosli, N. Probst-Hensch (2016) 'Long-term transportation noise annoyance is associated with subsequent lower levels of physical activity', Environmental International, 91: 341-349.

Kang, J. (2007) Urban Sound Environment, Taylor & Francis: United Kingdom.

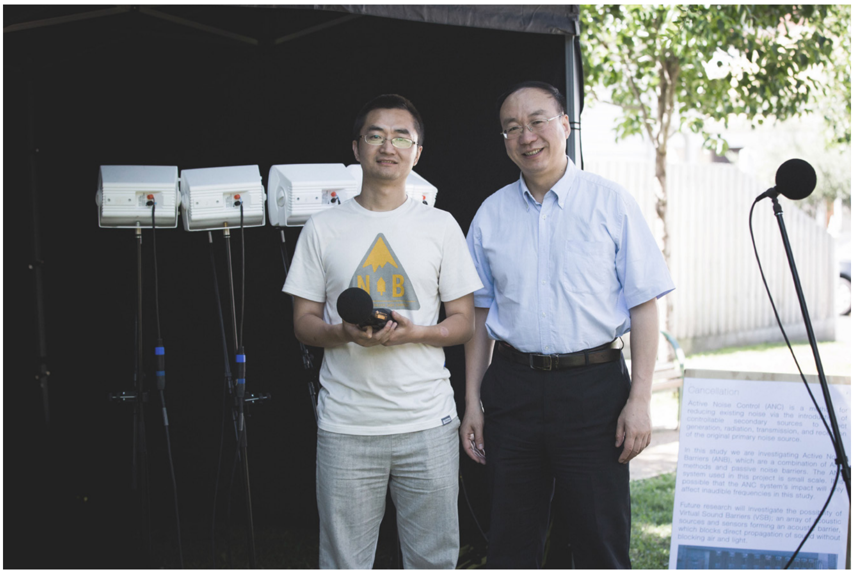
Lacey, J. (2016) Sonic Rupture, Bloomsbury: New York

Nyman, M. (1974) Experimental Music: Cage and Beyond, Cambridge University Press: United Kingdom.

Schafer, M. (1977) Soundscape: Our Sonic Environment and the Tuning of the World, Rochester, VT, Canada: Destiny Books.

# Cancellation

## Cancellation



Left to right: Sepei Zhao, Xiaojun Qiu

### Key Findings

**A circular Virtual Sound Barrier can create a quiet zone in a noisy environment where noise comes from many different directions.** We investigated the performance of an 8-channel circular VSB system with simulations, lab tests and field tests. Simulations show that the noise reduction of the system meets the design goals and decreases from 20 dB at 100 Hz to about 10 dB at 400 Hz. Lab tests show that the system is effective in reducing noise from 100 Hz to 250 Hz, and the noise reduction can reach 8 dB at 100 Hz. Field tests show that the noise reduction varies from 0.5 dB to 3.2 dB below 500 Hz except that at 125 Hz where the noise was not reduced.

**A planar Virtual Sound Barrier can create a large quiet area for traffic noise which comes from one direction.** The planar VSB system can reduce the noise from one direction, which is studied with simulations and lab tests. Simulations show that the planar VSB system can achieve 5-10 dB noise reduction in the frequency range from 50 Hz to 400 Hz. The experiment results show that the VSB system is effective in reducing the low frequency noise below 250 Hz, and the noise reduction can reach about 6 dB at 80 Hz.

**The challenge for practical implementation in the field is that multiple reference sensors are necessary in the system for multiple noise sources.** Preliminary listening tests show that the noise control effect can be clearly heard in the lab test but not in the field test. This was caused by the noise from multiple uncorrelated disturbances onsite. To gain maximum reduction of such a complicated spatial noise field, it is necessary to obtain maximum coherence between the reference signal and the error signal. This implies the use of multiple reference sensors, and a control strategy with multiple reference sensors, multiple secondary sources and multiple error sensors are necessary to achieve desirable noise reduction.

Circular Virtual Sound Barrier in the lab tests


Circular Virtual Sound Barrier in the field tests

# 1. Circular Virtual Sound Barriers

## 1.1 Introduction

Virtual sound barrier (VSB) is an array of loudspeakers and microphones forming an acoustic barrier, which creates a quiet zone without blocking air and light. Figure 1 illustrates an 8-channel circular VSB system, where 8 loudspeakers and 8 microphones are uniformly placed along a circle with radius $r_c$ and $r_e$, respectively. The controller minimizes the sum of the squared signals at the error microphones to create a quiet zone in the vertical dashed cylinder with radius $r_e$ and height $h_e$ in Fig. 1.

## 1.2 Simulations

For the circular VSB system shown in Fig, 1, the primary noise field at point **r** is assumed to consist of a number of plane waves with random amplitudes and phases from many different directions. When the radius of the error microphone array is fixed at 0.25 m, the control performance for different loudspeaker array radius, i.e., $r_c$ = 0.3 m, 0.5 m and 0.8 m are compared in Fig. 2(a), which shows that the noise reduction decreases with frequency. When the radius of the loudspeaker array is 0.5 m, the noise reduction is above 7 dB in the frequency range below 400 Hz; however, in the frequency range higher than 500 Hz, there is almost no noise reduction.

When the error microphones are placed 0.15 m in front of the loudspeakers, the control performance is shown in Fig. 2(b), which shows that the noise reduction decreases with frequency and the control performance deteriorates with increasing loudspeaker array radius. When the radius of the loudspeaker array is 0.3 m, the noise reduction is above 5 dB in the frequency range below 400 Hz.

Figures 2 shows that the simulation with $r_c$ = 0.3 m, $r_e$ = 0.15 m, he = 0.15 m gives the best results, hence the upper limit performance of this configuration is simulated by setting the cost function to minimise the overall sound potential energy in the quiet zone. The quiet zone inside the vertical dashed cylinder in Fig. 1 is uniformly sampled with a spatial interval of 0.02 m. Figure 3(a) shows the control performance, where the blue line denotes the practical results from minimising the overall sound potential energy at the 8 error microphones, and the red line indicate the upper limit performance. The vertical bars in Fig. 3 indicate the standard deviation from 100 trials. It can be observed that the noise reduction at 100 Hz to 500 Hz is close to the upper limit performance.

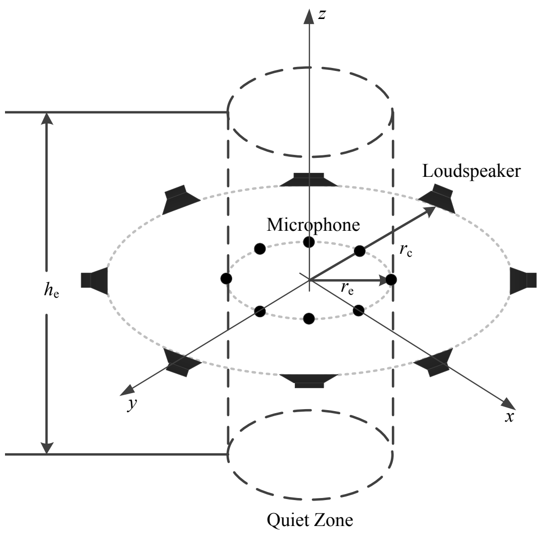
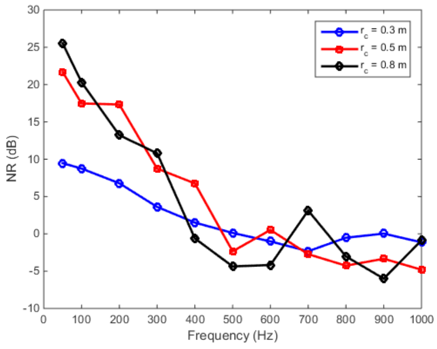


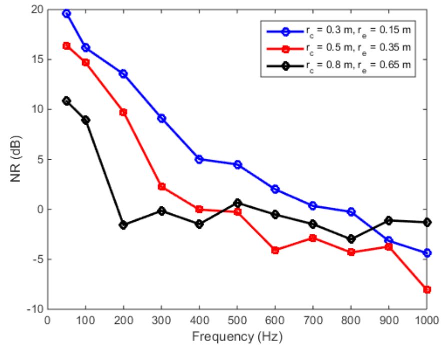

Fig 1. Illustration of an 8-channel circular Virtual Sound Barrier (VSB) system

## 1.3 Lab tests

An 8-channel circular VSB system was established in the SIAL POD which is a small room with sound absorbing materials finish on the floor and the walls, as shown in Fig. 4. The diameter of the loudspeakers and the error microphones were 1.4 m and 0.8 m, respectively. The primary noise was played back by two loudspeakers which were about 2.2 m from the VSB system. The reference microphone was between the VSB system and the noise sources, about 0.2 m in front of the noise sources. The Sound Pressure Level (SPL) at 10 points inside the error microphone array was measured in 1/3 octave bands when the ANC was off and on, respectively. The SPL with and without control is compared in Fig. 5(a) and the Noise Reduction (NR) is shown in Fig. 5(b). It can be seen that the VSB system is effective in reducing the noise from 100 Hz to 250 Hz, and the NR can reach about 8 dB at 100 Hz.




a




b

Fig. 2. Control performance with respect to the frequency of the noise signal for (a) different $r_c$ when $r_e$ = 0.25 m, he = 0.15 m. and (b) different $r_c$ when the error microphones are 0.15 m in front of the loudspeakers, he = 0.15 m.

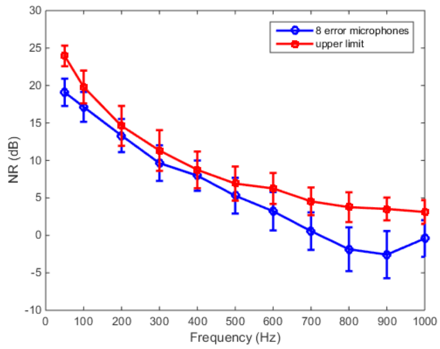
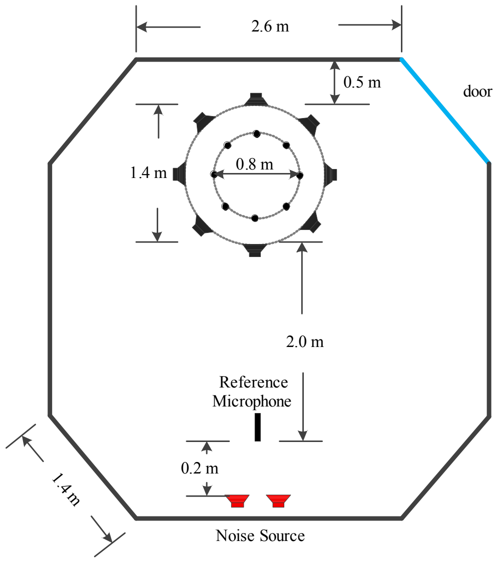



Fig. 3. The upper limit performance with respect to the frequency for the circular VSB ($r_c$ = $h_c$ = 0.15 m, $r_c$ = 0.30 m). The vertical bars indicate the standard deviation from 100 trials.

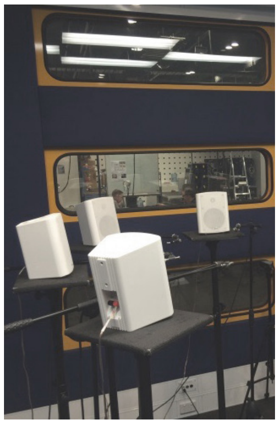
## 1.4 Field tests

An 8-channel circular VSB system was established in the field test at Richmond, Victoria, as shown in Fig. 6. The diameter of the loudspeakers and the error microphones were 1.2 m and 0.8 m, respectively. The primary noise signal was the traffic noise from the road behind a wall. The wall is about 5 m high and 18.5 m away from the VSB system. The reference microphone was a unidirectional microphone which was put between the VSB system and the noise sources, about 4 m from the VSB system. The error microphones were all omnidirectional microphones.

The SPL at the centre of the error microphone array was measured in 1/3 octave bands with ANC off and on, respectively, and the SPL with and without control is compared in Fig. 7(a). The noise reduction is shown in Fig. 7(b). The NR varies from 0.5 dB to 3.2 dB below 500 Hz except that at 125 Hz where the noise was not reduced. Just for comparison, numerical simulation results are also shown in Fig. 9(b). In the simulations, the arrangement of the loudspeakers and error microphones were the same as that in the experiment, and the primary noise was modelled as a noise source plane consisting of 200 point sources with random amplitudes and phases. It can be observed from Fig. 7(b) that the simulated NR decreases with frequency, from about 19 dB at 50 Hz to about 5 dB at 500 Hz, which is much higher than that measured in the experiments.

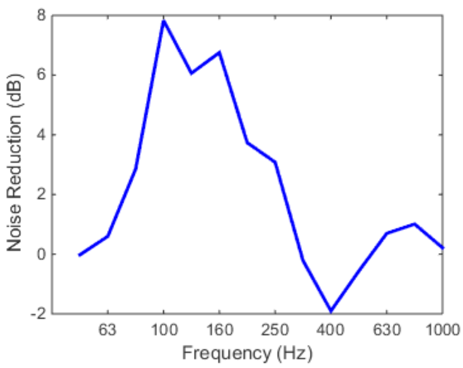



a

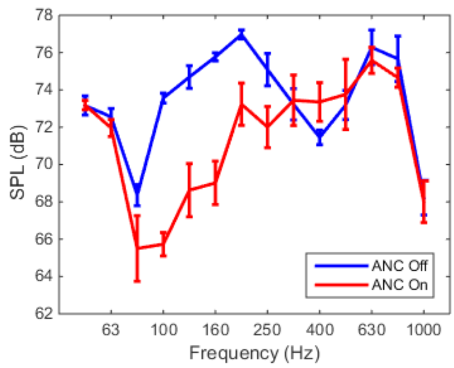


b

Fig. 4. (a) Diagram and (b) photo of the circular VSB system in the POD.

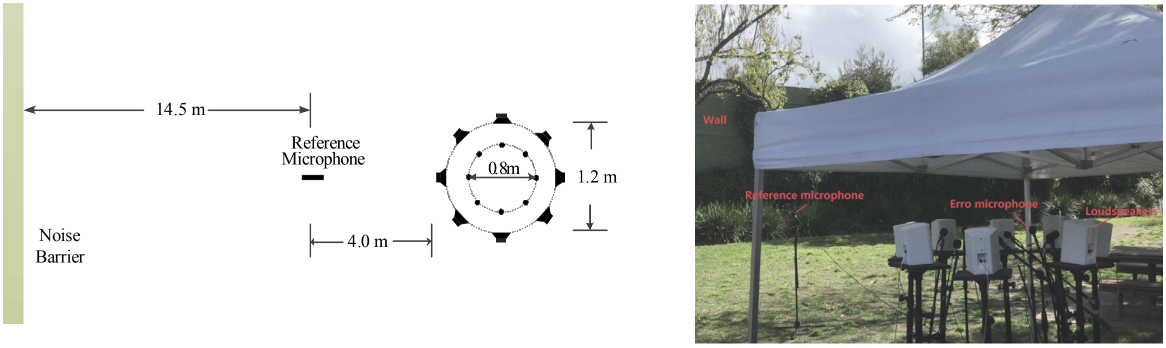



a




b

Fig. 5. (a) SPL when the ANC system is on (red line) and off (blue line) and (b) NR at different frequencies for the 8-channel circular VSB system in the POD.

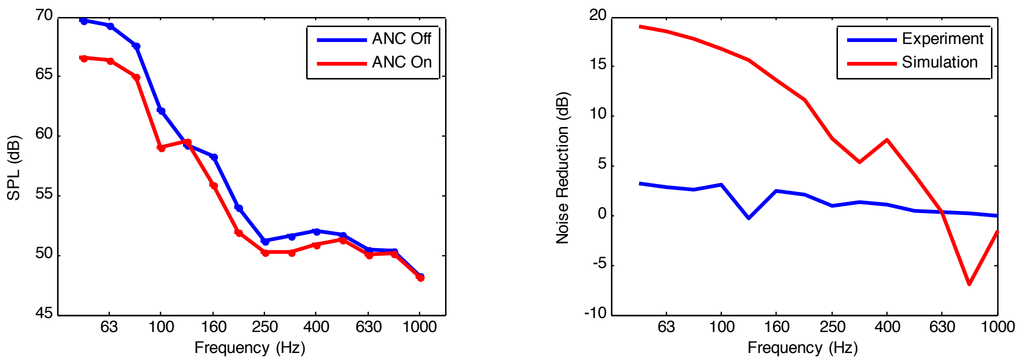



a b

Fig. 6. (a) Diagram and (b) photo of the planar VSB system in the field test at Richmond.

## 1.5 Discussions

The traffic noise spectrum shown in Fig. 7(a) is excellent for ANC and better performance (e.g. 6 dB to 10 dB noise reduction below 200 Hz) should be obtained in the experiments. One main reason for the non-satisfactory results in the current measurements is that only one reference microphone was used in the experiments so the noise from other directions cannot be captured. Further investigations on multiple references active noise control systems are necessary to approach better results




a b

Fig. 7. (a) SPL when the ANC system is on (red line) and off (blue line) and (b) NR at different frequencies for the 8-channel circular VSB system in the field test at Richmond, Victoria.

## 1.6 Conclusions

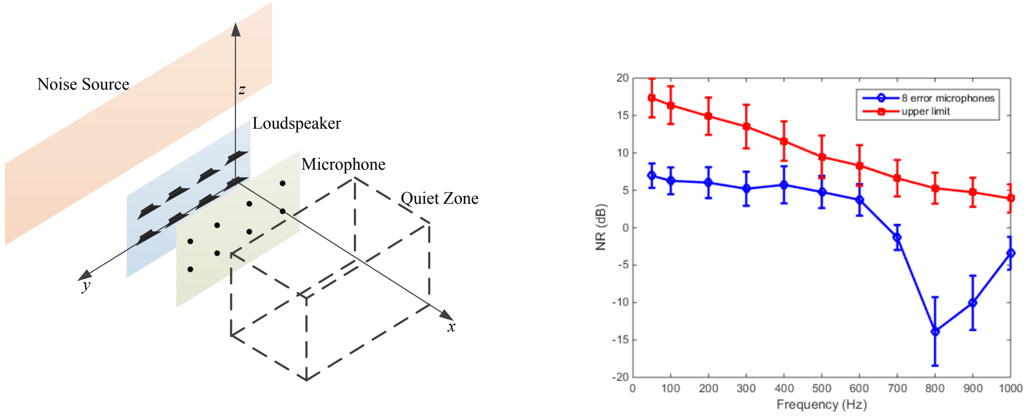
The performance of an 8-channel circular VSB system was investigated with numerical simulations, lab tests and field tests. In the simulations, it was found that the noise reduction is above 7 dB in the frequency range below 400 Hz when the diameter of the loudspeaker array and the error microphone array was 1.0 m and 0.5 m respectively. The noise reduction of the circular VSB system was close to the upper limit performance of the system theoretically which decreases from 20 dB at 100 Hz to about 10 dB at 400 Hz.
Lab tests of an 8-channel circular were carried out in the SIAL sound POD, where the loudspeakers were uniformly placed along a circle with a diameter of 1.4 m to create a quiet zone with a diameter of 0.8 m. The experiment results showed that the system is effective in reducing the low frequency noise from 100 Hz to 250 Hz, and the NR could reach about 8 dB at 100 Hz. Preliminary listening tests showed that the reduction could be apparently perceived when the system is on, especially when there is a heavy trucking crossing.

An 8-channel circular VSB system was then established to cancel the traffic noise on site at Richmond, Victoria. The diameter of the loudspeakers and the error microphones were 1.2 m and 0.8 m, respectively. It was found that the noise reduction varies from 0.5 dB to 3.2 dB below 500 Hz except that at 125 Hz where the noise was not reduced. Preliminary listening test showed that no difference could be perceived in the field test. This is because there was only one reference microphone so the VSB system could only reduce the noise from one direction. Because the noise from other directions was not reduced, reduction of the total sound pressure level was little.
Future work will investigate the performance of the multiple independent ANC system on reducing noise from many different directions and will develop the fully coupled multiple reference multi-channel ANC system which is expected to have better performance than the multiple independent ANC system.

# 2. Planar Virtual Sound Barriers

## 2.1 Introduction

An 8-channel planar VSB system is illustrated in Fig. 8(a), where 8 loudspeakers and 8 microphones are placed at two parallel planes to reduce the noise from one direction behind the system. The controller minimizes the sum of the squared signals at the error microphones to create a quiet zone in the dashed box in Fig. 8(a).




a b

Fig. 8. (a) Illustration of an 8-channel planar Virtual Sound Barrier (VSB) system and (b) the upper limit performance with respect to the frequency for the planar VSB. The vertical bars indicate the standard deviation from 100 trials.

## 2.2 Simulations

For the planar VSB system shown in Fig. 8(a), the primary noise field at r was assumed to come from one direction and was modeled as many point sources with random phase, which were randomly distributed in the noise source plane in Fig. 8(a). The noise source plane was 20 m long and 0.3 m high, and was 2 m behind the loudspeaker array, and 300 point sources were used to simulate the primary sound. The microphone array was 0.15 m in front of the loudspeaker array. The distance between two loudspeakers was 0.3 m. The quiet zone was 0.2 m in front of the microphone array, in a box with dimension 0.5 m × 0.9 m × 0.3 m.

The upper limit performance of the system was simulated by setting the cost function to minimise the overall sound potential energy in the quiet zone. The quiet zone inside the dashed cylinder in Fig. 8(a) was uniformly sampled with a spatial interval of 0.02 m. Figure 8(b) compares the practical results from minimising the overall sound potential energy at the 8 error microphones (blue line) with the upper limit performance (red line), where the vertical bars indicate the standard deviation from 100 trials. It can be observed that the planar VSB system can achieve 5-10 dB noise reduction in the frequency range from 50 Hz to 600 Hz, but cannot reduce the noise level in the frequency range higher than 700 Hz, and that the practical results with error microphones in front of the loudspeaker array are much lower than the upper limit performance.

## 2.3 Lab tests

An 8-channel planar VSB system was established at the door of the SIAL POD to reduce the noise propagating from outside to inside, as shown in Fig. 9. The interval distance between the loudspeakers was 0.4 m, and the error microphones are 0.15 m in front of the loudspeakers. The primary noise was played back by loudspeaker which was about 2.2 m from the door outside the POD. The reference microphone was between the VSB system and the noise sources, about 0.2 m in front of the noise sources. The Sound Pressure Level

(SPL) at 5 points inside the POD was measured in 1/3 octave bands when the ANC was off and on, respectively. The SPL with and without control is compared in Fig. 10(a) and the NR is shown in Fig. 10(b). It can be seen that the VSB system is effective in reducing the noise below 250 Hz, and the NR can reach about 6 dB at 80 Hz.

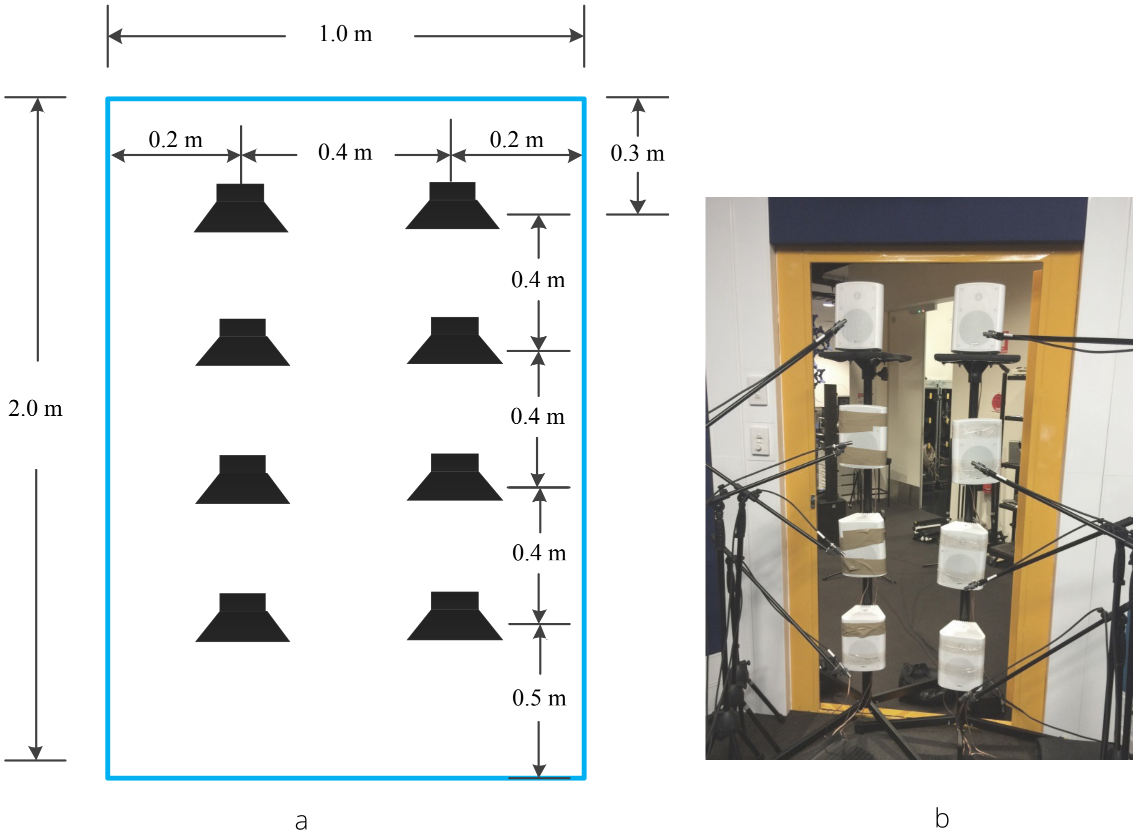



Fig. 9. (a) Diagram and (b) photo of the planar VSB system in the POD.

## 2.4 Conclusions

The planar VSB system that the loudspeakers are placed in a plane to reduce the noise from one direction for creating a quiet zone in front of the system was studied with simulations and lab tests. Simulations showed that when the noise source plane was 2 m behind the loudspeaker array and the microphone was 0.15 m in front of the loudspeaker array, the planar VSB system could achieve 5-B noise reduction in the frequency range from 50 Hz to 400 Hz, but could not reduce the noise level in the frequency range higher than 700 Hz. The simulation results of the planar VSB system with error microphones in front of the loudspeaker array were much lower than the upper limit performance.

An 8-channel planar VSB system was established at the door of the SIAL POD to reduce the noise propagating from outside to inside. The experiment results showed that the VSB system was effective in reducing the low frequency noise below 250 Hz, and the NR could reach about 6 dB at 80 Hz. Preliminary listening test showed that a big difference could be heard for the planar VSB system in the lab tests. Future work will explore the performance of the planar VSB system when there are multiple noise sources present simultaneously. Multiple reference multi-channel ANC system will be developed to improve the noise reduction performance.

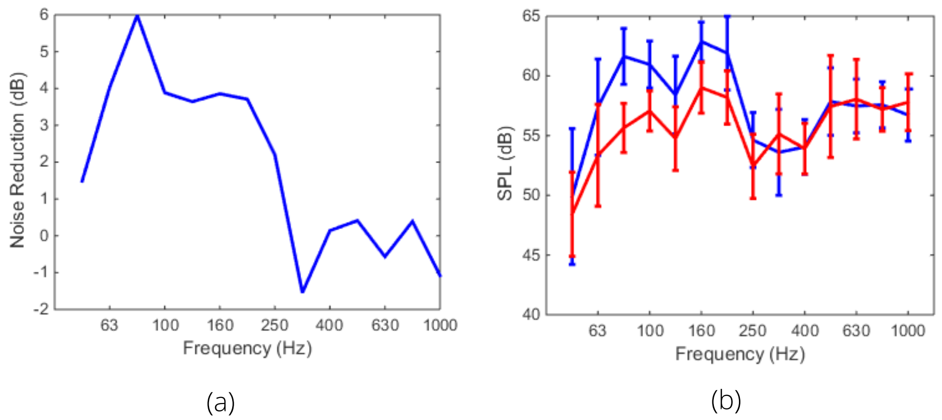



Fig. 10. (a) SPL with the ANC system on (red line) and off (blue line) and (b) NR at different frequencies for the 8-channel planar VSB system in the POD.

## 3. Multiple Reference Sensor Systems

### 3.1 Introduction

Most applications of current ANC systems have been focused on using a single reference signal; the work on multiple reference ANC is scarce. When there are multiple noise sources, multiple reference sensors are needed to generate complete reference signals [1]. It is noted that many noise fields are due to multiple uncorrelated or partially correlated disturbances. To gain maximum reduction of the noise field, it is necessary to obtain maximum coherence between the reference signal and the error signal. This implies the use of multiple reference sensors and associated signals [1]. Therefore, in a complicated spatial noise field where there are several noise sources, a control strategy with multiple reference sensors, multiple secondary sources and multiple error sensors is needed to achieve desirable noise reduction [2].

Mikhael et. al discussed the noise coupling in a multiple source environment and studied optimal filter structures for multiple reference ANC [3]. Wallace et. al. proposed parallel adaptive filter structures for the multiple reference ANC inside a vehicle [4]. An average noise reduction of 16 dB is reported. In principle, the number of reference sensors needed to achieve maximum coherence should be more than the number of noise sources. Traditional coherence techniques may be applied for noise source identification [5]. The effectiveness of coherence techniques depends not only upon the source coherence, but on the extent of measurement contamination [6]. Another criterion for the selection of reference sensors to detect noise sources has been proposed based on maximum potential control and the relative convergence rate [7]. A method to increase the convergence speed by using uncorrelators for the ANC in a multiple noise source environment has been presented by Masato et. al. [8].

With the above mentioned studies, there have no practical application of the multiple reference multi-channel ANC systems on the traffic noise reduction scenario. In the future work, a multiple reference multi-channel VSB system will be developed, as illustrated in Fig. 11 where the multiple reference system is compared with the current single reference system.

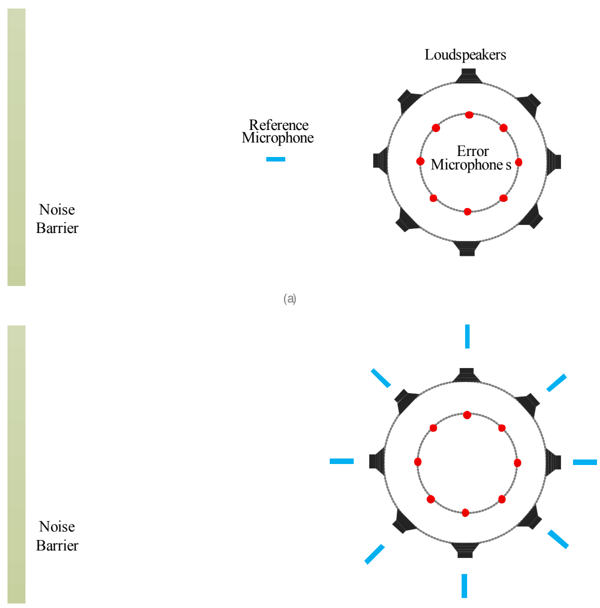



Fig. 11. Diagram of the (a) single reference and (b) multiple reference 8-channel circular VSB system

## 4. Future Work

### 4.1 A 20 m long active noise barrier

In the future, the ANC system will be installed on top of the existing passive noise barrier to form an Active Noise Barrier (ANB) system so that the noise reduction performance can be enhanced. An illustrative diagram of such a system is shown in Fig. 12, where a quiet zone denoted by the dashed box will be created. The ANB system will be 20 m long. To eliminate the low frequency noise below 500 Hz for a 30 m long barrier, around 150 channels will be needed with 5 channels per meter. For such a prototype system, one channel costs about $1000, so the total cost would be around $150,000 (excluding installation and maintenance cost). The outcome is a minimum of 3 dB extra noise reduction on the existing barrier. With mass production, the cost of such systems can be reduced significantly.

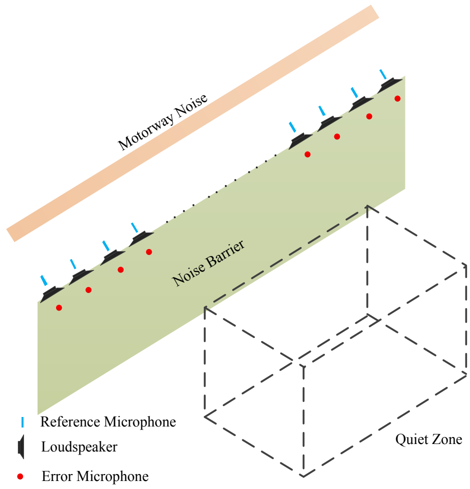



Fig. 12. Diagram of the Active Noise Barrier (ANB) system with the ANC system installed on top of the noise barrier

## 4.2 A 3 m diameter circular virtual sound barrier

Another system that will be built in the future is a circular VSB system with a diameter of 3 m. The circular VSB system will be established with multiple reference sensor ANC system to create a quite zone inside the error microphone array, as shown in Fig. 13. The system will consist of about 140 channels with 5 channels per wavelength for the noise below 500 Hz. The cost would be around $140,000 with $1000 per channel (excluding installation and maintenance cost).

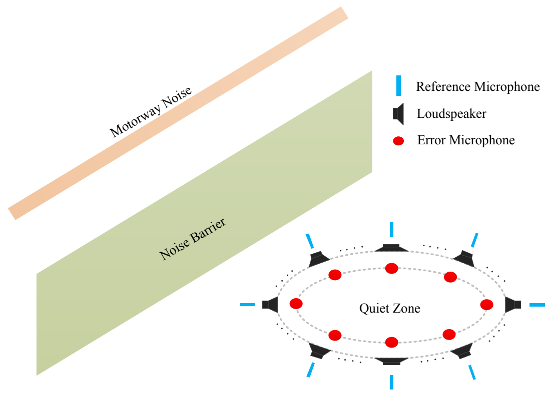



Fig. 13. Diagram of a multi-channel circular Virtual Sound Barrier (VSB) with multiple reference microphones.

## 4.3 A noise proof window/door with natural ventilation

Finally a noise proof window with natural ventilation illustrated in Fig. 14 will be explored in the future. The ANC system will be installed on the window frame to prevent the outside noise from propagating to inside the room through the window. Previous study showed that with proper design, the ANC system can achieve more than 10 dB extra attenuation [9].

For a window with size 3 m × 2 m, an ANC system of about 75 channels will be needed to effectively reduce the noise below 500 Hz with 5 channels per wavelength. The cost will be around $75,000 with $1000 per channel (excluding installation and maintenance cost).

The noise proof window system shown in Fig. 14 can be combined with the active noise barrier system shown in Fig. 12 to further reduce the noise level inside the room.

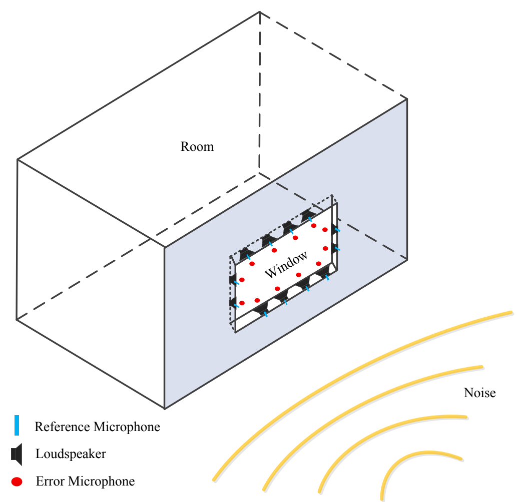



Fig. 14. Diagram of a noise proof window with natural ventilation where the ANC system is installed on the window frame.

# References


Y. Tu, “Multiple reference active noise control,” Virginia Polytechnic Institute, Master Thesis, 1997.

T. J. Sutton, S.J. Elliott, A. M. McDonald and T. J. Saunders, “Active control of road noise inside vehicle,” Noise Control Engineering Journal, 42(4), 137-147, 1994

W. B. Mikhael and P. D. Hill, “Active noise cancellation in a multiple noise source environment,” IEEE International Symposium on Circuits and Systems Proceedings, p. 3 vol. 2915, 2399-402, 1988

R. B. Wallace, R. A. Goubran, “Parallel adaptive filter structures for acoustic noise cancellatin,” IEEE International Symposium on Circuits and Systems, P. 6 vol. 3028, 525-8, 1992.

J. Y. Chung, M. J. Crocker, “Measurement of frequency response and multiple coherence function of the noise generation system of a diesel engine,” Journal of the Acoustical Society of America, 58, 635-642, 1975.

M. E. Wang and M. J. Crocker, “On the application of coherence techniques for source identification in a multiple noise source environment,” Journal of the Acoustical Society of America, 74(3), 861-872, 1983.

C. M. Heatwole and R. J. Berhard, “Reference transducer selection for active control of structure borne road noise in automobile interiors,” Noise Control Engineering, 44(1), 1996.

A. B. E. Masato, G. Y. Chen and T. Son, “A method to increase the convergence speed by using uncorrelators in the active control of multiple noise sources,” Proc. of INTER-NOISE 93, 759-762, 1993.

H. Huang, X. Qiu and J. Kang, “Active noise attenuation in ventilation windows,” The Journal of the Acoustical Society of America, 130(1), 176-188.

# Ethnography

## Ethnography

Left to right: Sarah Pink, Shanti Sumartojo and Melisa Duque

### Key Insights

**Sound transformation has the potential to create new forms of well being:** Because sound transformation creates new value by transforming existing annoying but nevertheless familiar elements of the everyday into pleasurable ones, it has the potential to generate new forms of wellbeing on two levels: it first pushes into the background the elements of everyday sounds that are annoying, as well as the feelings, values and judgements that make these annoying; and it second, creates localities and experiences in everyday life that generate senses of wellbeing, calm and relaxation.

**The ethnographic methodology proved to be highly effective** in enabling us to get under the surface of what participants say. It provided a means through which we could collaborate with them to interrogate their emotional and sensory feelings about freeway sound in situ in their homes and gardens and both freeway and transformed sound in the park. Ethnographic-theoretical analysis enabled us to: interpret these experiences as part of a multi-sensory configuration of experience, and to understand this as part of the social and moral dimensions of living in a neighbourhood; develop an understanding of how and why the transformed sounds led to senses of wellbeing. A design anthropological and futures approach enabled us to focus on the ways that the sound transformation experiences opened up imagined future soundscapes for participants and enabled us to gain insights into how future transformed soundscapes could become significant generators of well being in public space.

# Key Findings

While participants' **sensory experience of the freeway accounted for sound, they went beyond the category of sound to included sensory categories of vision, smell and vibration.** This is important to keep in mind in relation to the discussion below, where we show how the sound transformation experiences enabled participants to speak of other different ways of feeling in the park, thus meaning that the locality was experienced differently through the sound transformation, and this was often connected to sensory and emotional senses of wellbeing, and ways of 'feeling'.

Our ethnography demonstrated **how participants attributed and explained sound and noise and the moral connotations that they attached to these sounds.** Participants usually attributed freeway and other neighbourhood sounds to other humans, and understood them as being produced through certain activities, that they often placed a moral judgement on. It was often in relation to this that they felt a sense of annoyance, inevitability or acceptance or concern about these sounds. This explains how participants interpreted freeway sound in relation to traffic and drivers and has implications for the ways that transformed sound liberates them from such interpretations and the emotions that they invoke.

Participants expected freeway and others sounds to change during the course of the day and night and over the weekly cycle, according to weekly routines of work and travel. Therefore there are particular times in daily and weekly routines and cycles where sound transformation or cancellation might be perceived as more useful or desirable for both residential homes and public space. This would both relate to people's uses of public space near to freeways, as well as to how traffic noise changes temporally.

**Participants had existing ways of getting used to or adapting to the annoyance of freeway noise, or improvising** in their homes in order to be able to live with the sound in a way that felt sufficiently comfortable. This suggests that they were able to attune to this sound as part of their everyday environments, or 'block it out', particularly when they valued other elements of these environments. However, because our participants were residents of the area close to the freeway, they were people who had been both willing to move to such an environment and/or had become accustomed to the sound already. Future research would be needed to explore the perceptions and experiences, and the possible benefits of sound transformation for people contemplating moving into such areas or those who had felt that they would not wish to live in areas with freeway sound.

**Participants tended to concur in relation to the experience of each sound transformation.** In general they were in favour of sound transformation as an enhancement of the experience of the park in relation to traffic noise. Sound transformation was appreciated for its 'natural' feel, and often understood as a composition rather than a live transformation.

**Sound transformation involves a process of creating value out of something that was previously an annoyance.** The value or potential value of sound transformation lies mainly in its capacity to create more pleasant versions of existing annoyances, and to make relaxing, and calming environments.

**Sound cancellation was appreciated as a valuable experience** that could be potentially offered in site-specific contexts.

## Recommendations

To consider and test how sound transformation experiences would best be brought into public space in ways that will optimise their beneficial effects to the public; and to similarly investigate how and where they would benefit domestic space in residential areas. Further to this to develop sound transformation technologies with an eye to how they might become automated in relation to sensor technology data and user community data produced in smart or other digital city configurations which will enable their temporal rhythms to follow those of citizen's everyday life experiences.

To develop further ethnographic research that builds on the findings of this study, and is developed in collaboration with sound transformation design research, in order to ensure that future installations are site and user-appropriate.

# 1. Introduction

## 1.1 The Ethnographic-theoretical approach

In this research we developed a sensory ethnography (Pink 2015) research design in dialogue with theoretical understandings of sensory experience and environment drawn from phenomenological anthropology (Ingold 2000, 2010) and a design anthropological (Smith et al 2017) and future anthropologies (Pink and Salazar 2017) approach to understanding the temporalities of everyday experience and possible futures.

## 1.2 The Ethnographic methodology and fieldword sites

### 1.2.1. The ethnography

The ethnographic research focused on producing new in-depth knowledge, understandings and insights into:

- How residents of the streets adjoining the freeway experienced freeway sound in their everyday lives in the neighbourhood and in the research site
- How visitors to the park (including residents in the streets adjoining the freeway) experienced the freeway sounds and the sound transformation and cancellation experiences created by the sound design and acoustic engineering teams.
- The implications regarding the value of sound transformation in residential areas

A tailored ethnographic research methodology was designed to undertake this research, using video recording in order to produce a deep understanding of participants' sensory experiences of their everyday environments in the home and park sites, and to understand the place, importance and value of sound with in this.

Working in a team of three ethnographers, we recruited 23 research participants, seven women and sixteen men. Participants were a combination of local residents dropping into the site, most of whom were regular visitors who used the park for exercise, to walk their dogs or to play with their children on the playground equipment. Other research participants had come to the park specifically to hear the effects of the sound transformation and cancellation technologies, happened to be passing during the installation, or were viewing a property that was for sale overlooking the park.

### 1.2.1. Homes in the neighbourhood

Four participants were interviewed in their homes in the neighbourhood of the park. They were asked to show researchers around their homes, while being video recorded. During these research encounters we explored the sounds and other sensory experiences of participants homes and gardens, how externally originating sounds changed during the day, the everyday routines and activities in the home that generated sounds, and explored how they managed the sound ecologies of their homes, and improvised in their homes in order to create particular sensory experiences of home, with a focus on sound (see Clip 1). Other participants who lived locally also discussed with us their experience of freeway sound while living in the area.

Figure 1: a glimpse of the soundwall from the front porch of one local participants' home.

### 1.2.3. The park

In the park the participants were asked to participate in two activities, both of which were video recorded:

1. To listen to a series of four different sound transformations, and one example of sound cancellation. Participants were invited to discuss with us their experiences of the different sound transformation and cancellation scenarios.
2. To participate in a sound walk beginning outside the park and proceeding along the wall alongside the freeway to the opposite end of the park. During this walk participants were invited to comment on and discuss what they could hear and feel. Our interviews in the park invited participants to walk with us from a small gap in the soundwall adjacent to the park (see Figures 1 and 2), telling us what they could hear and how they felt about it. We walked with participants into the park and sat with them in the sound transformation tent, discussing their impressions of the four distinct transformations.

These video materials were then analysed in order to gain an understanding of how the participants had experienced and conceptualised both the sounds of the freeway as they approached it and walked alongside it through the park, and the different sound transformation scenarios.

Figure 2: Two of the project researchers listen at a gap in the sound wall as part of a guided soundwalk.

Figure 3: The entry to the Charles Evans Reserve from the sound wall pictured above in Figures 1 and 2.
Photo credit: Melisa Duque

Figure 4: Looking back at the sound transformation tent from inside Charles Evans Reserve.

Photo credit: Melisa Duque

## 1.3 Key Insight

The ethnographic methodology proved to be highly effective in enabling us to get under the surface of what participants say. Instead it provided a means through which we could collaborate with them to interrogate their emotional and sensory feelings about freeway sound in situ in their homes and gardens and both freeway and transformed sound in the park. Ethnographic-theoretical analysis enabled us to: interpret these experiences as part of a multi-sensory configuration of experience, and to understand this as part of the social and moral dimensions of living in a neighbourhood; develop an understanding of how and why the transformed sounds led to senses of wellbeing. A design anthropological and futures approach enabled us to focus on the ways that the sound transformation experiences opened up imagined future soundscapes for participants and how and to gain insights into how future transformed soundscapes could become significant generators of well being in public space.

# 2. Research findings

## 2.1 Freeway sound as part of the experience of locality

Existing ethnographic research and theory has demonstrated that the experience of sound, and other sensory categories (eg vision, touch, smell, taste) are not different or separate modes of experience, but are rather culturally specific categories that human beings use to express experiences that are in fact much more mixed up and messy (see Pink 2015). This means that when we think about how motorway sound is part of the experience of any locality (for instance, a home and garden or a community park), we need to understand how it is experienced and perceived and how it is expressed in categories that make sense to the participants in research. This also means that sound transformation as well as untransformed freeway sound needs to be understood as always emerging in and perceived in relation to wider sensory environments.

Our research with participants was undertaken in two key sites - their homes and gardens and in the community park directly next to the freeway. In both of these contexts we investigated how the sound of the freeway was both part of the wider sensory experience of these localities and how it was entangled with other sounds in those sites.

This section demonstrates how we cannot separate out freeway sound from the sensory experience of everyday sites and localities where it is experienced, and that participants in our research did not necessarily usually think of the freeway sound independently of thinking about their wider experience of the environment.

### 2.1.1 Freeway sound as part of everyday soundscapes:

We found that the freeway sound was usually thought of as part of living in the particular area that it impacted in and tended to be perceived as a given element of the environment. Local residents we interviewed highly valued living in the area, one describing it as 'quiet' because there was no through traffic on his road, despite living only approximately 50 metres from the freeway. Freeway noise, while perceptible, was for these residents who valued the area, less important that the overall amenity of living in the area. For example, for one participant this meant that he could walk to work in the area, and for another participant living near the freeway was an advantage since he had to drive to work and his easy access to the freeway meant that his travel time was reduced by 30 minutes. The neighbourhood also has quick and easy access to the city centre by public transport and for some participants was also their main area for socialising. It is important to keep this context in mind since it bears on the question of how freeway sound is interpreted within the wider sensory and emotional, as well as logistical and social elements of everyday life and how value is attributed in relation to other aspects of the neighbourhood.

We learned that freeway sound had become part of the everyday soundscapes of participants. For instance, one participant, J, lived less that 50 meters from the freeway (see Figure 1). He had lived there just over two years and loved living in the area. He explained how the sound of the motorway mixed with the normal sounds in his house:

> It is something that you definitely do hear, but maybe it's something that I've become accustomed to because I live here everyday. I actually hear, there's a few choppers that come around here, I don't know if it's because we're close to the city, I notice them a little bit more than I do the actual cars, but that being said when there's a big semi-trailer or a large truck that makes a lot more noise than the general, standard car, then it does get my attention, yes. But it wouldn't be something that I'd notice everyday.'

Inside the house, the motorway sound was much less prominent than other common noises:

> Now that we're inside, it's gone the noise, I can hear the fridge humming louder than I can the cars. I don't really hear the noise much when I'm in here [front room]...in here it's quite peaceful.

Other domestic sounds, including the regular routine of the washing machine in family homes or shared houses, and the TV also tended to contribute to the domestic soundscape meaning that once in the home, freeway sound would often not be perceived. As one participant, C, who lived in the area, explained it was common for certain sounds to slip beneath notice as they became increasingly familiar (see Clip 2)**.**

In this particular context therefore the freeway sound was interpreted as an inevitable sound of everyday life. This does not mean however that it was valued, or that it was desired, and indeed one participant noted that he was probably woken up twice a week during the night by a loud noise from the freeway, but would simply go back to sleep. As such freeway sound was, as one participant noted a 'normal' sound. Indeed it was a sound that participants had learned to cope with and to improvise around freeway sound as they lived with it in their homes and gardens (see section 2.2), which also contributed to the way that they normalised it. In contrast, other aspects of the soundscape tended to stand out. Examples of this were neighbourhood dogs barking and the sound of the megaphones from rowers on the nearby Yarra river. As one participant, J, who lived close to the freeway explained:

> one of the most annoying sounds we get, it isn't the cars, it's actually the rowers. We've the Yarra River, which is just over the freeway and we get a lot of rowers... you get a guy on a bike with a megaphone which communicates with their rowers and they talk really loud, and the megaphone is really loud. And depending on which side of the Yarra they are, most times they're on the far side with their megaphone pointing towards this side...I can actually hear that and that's what annoys me the most...it's like someone's talking in your ear and you can hear them talking and once again it's not a constant sound, it's more up and down and fluctuating and...it annoys me more than the cars...

## Key Finding

These experiences of sound are important to keep in mind in relation to the further findings of this report, since they demonstrate that while freeway sound is not desirable, participants thought of it as 'normal' and were able to 'normalise' it, and it was at most times not something that participants were conscious of.

### 2.1.2. Freeway sound in the Cremorne site as part of wider sensory experience

Existing ethnographic research and theory has demonstrated that the experience of sound, and other sensory categories (eg vision, touch, smell, taste) should not be considered to be different or separate modes of experience, but are rather culturally specific categories of experience that human beings use to express experiences that are in fact much more mixed up and messy (see Pink 2015 for a summary of this). This means that when we think about how freeway sound is part of the experience of any locality (for instance, a home and garden or a community park), we need to understand how it is experienced and perceived and how it is expressed in categories that make sense to the participants in research. This also means that sound transformation as well as untransformed freeway sound needs to be understood as always emerging in and perceived in relation to wider sensory environments.

Participants who used the park did not find the freeway noise very surprising. As one participant pointed out, city parks tend to be noisy. Others found the park a place to seek refuge from the busyness of work nearby, a good place for dog-walking and for taking their children to the playground. In this sense the park could be seen to offer them something that was not available elsewhere in the neighbourhood. Moreover there were reasons why participants liked the park, which could be seen as 'trade-offs' in relation to the sound, for example, it was seen to be a quite safe and enclosed place precisely because it was closed off by the wall that hid the freeway from sight. As one participant noted this meant that they did not have to worry about their child running out of the park on to the road, and in this sense generated a feeling of security.

Figure 5: The wall enclosing the park and hiding the freeway.
Photo credit: Melisa Duque.

The park was understood by participants as a visually pleasing and agreeable site, which was improved and enhanced by the sound transformation possibilities.

Participants did not always discuss the experience of the freeway in terms of sound. For example, the idea of a 'feeling in the body' emerged as one way of describing the experience. This concurs with other sensory ethnography research (eg. Geurts 2003, Pink 2015) which has shown that there are some types of sensory experience in which conventional sensory modalities overlap and cannot be described using the sensory categories of vision, sound, smell, touch and taste. For example:

- A, a resident who lived directly next to the park site described the effect of vibration from the road in his home: 'That's probably the only side that sometimes, again it is not very common, but sometimes when bigger trucks just the shakes the vibration might be a little bit annoying, and if you have like frames and stuff hang on, but even that one I mean it's not really that bad its ok'.

- M, a local homeowner who had been in the area for six years, described his perception of motorway noise in his backyard, pictured below: 'I think the perception of having another room in here that you're a little bit more surrounded and enclosed by vegetation, I think that will dampen the noise, not physically but certainly psychologically because you'll feel like, well I'm in a separate room and I don't know where that freeway is.'

Figure 6: M's backyard, about 50 metres from the Charles Evans reserve.

- N expressed this in terms of physical resonance in her body: 'As soon as I heard it I felt calmer, and I can feel it resonating in my chest, so I feel more grounded, and then the traffic noise takes a back seat to the way that it interacts with the trees' (see Clip 3).

The accounts of vibration, resonance or a sense of spatial enclosure extended into accounts by participants that expressed sound in terms of movement, which they compared to other types of movement, often using gesture to help explain their sensory perceptions.


Figure 7: T gestures to explain the wave-like sound of the passing motorway traffic.

- This included describing it as 'like a wave', as T told us (Figure 7), or as N explained: 'it's just like a wave, it's just a constant wash, sounds don't have a start or a finish, they just mould into each other, although a wave has a crash.'

- Similarly, S described the transformed traffic noise in terms of the sound itself moving: [it]kind of reflects the length and the duration of well I suppose the traffic, um but, I can see big long pipes and kind of this sound is traveling down, I like how it breathes as well, I mean it's very subtle, it just kinda sits in there, but it seems like it has a life of its own I suppose (the sound)... the breathing of the sound itself.

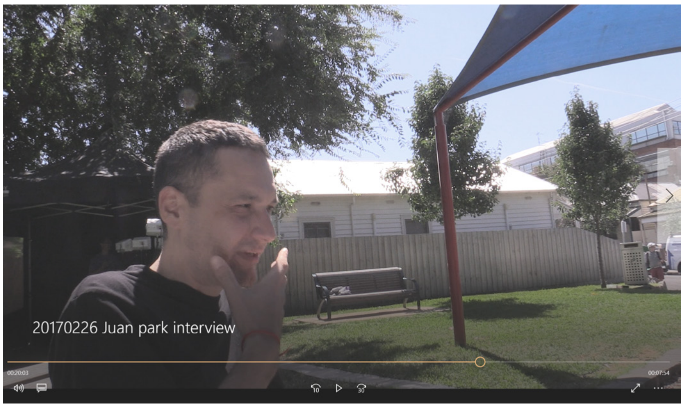



Figure 8: J's gestures shows his reaction to the smell of the motorway and the imagined particles circulating in the air in the Reserve.

- Finally, smell, was a part of how people experienced the site, and this co-mingled with its auditory and visual elements. L, who did not live locally, explained this in terms of his previous experiences of living near a busy road: 'Yeah you don't want to open the windows, first because you don't want the sound to be that loud, and second because there's like I don't know like dust everywhere, it's terrible, because I think there's not only the combustion of the engine, but it's also the brakes of the car, they actually you know every time you brake, there's these little particles that go into the air and fly, this is very tiny, yeah the worst.'

### 2.1.3. Key Findings

While participants' sensory experience of the freeway accounted for sound, they went beyond the category of sound to included sensory categories of vision, smell and vibration. This is important to keep in mind in relation to the discussion below, where we show how the sound transformation experiences enabled participants to speak of other different ways of feeling in the park, thus meaning that the locality was experienced differently through the sound transformation, and this was often connected to sensory and emotional senses of wellbeing, and ways of 'feeling'.

The findings of this ethnographic section need to be understood in the context of the ways that participants already felt comfortable with the wider material, visual and sensory environment of the park itself, and the relationship this bore to the freeway.

## 2.2 Making sense of sound and noise

In this section we examine how participants made sense of the sounds that were part of their everyday lives at home and in the park, and how they explained them.

Generally participants tended to talk about sound and noise using terms such as annoying or pleasant. In this particular research context they did not often suggest that sounds had created more powerful emotions for them. However they generally engaged with sound transformation as a potential source of well being, beyond it simply being pleasant.

### 2.2.1. The origins of sounds

In this section we outline how participants understood sound in relation to its possible perpetrators, and the implications of this for understanding both their experiences of freeway sound and of transformed sound.

Neighbourhood noises such as neighbours having a party, a dog left outside and barking, and a baby crying all have different impact depending on why participants think the noise is happening and the motivations of its author. One good example that participants specifically compared with freeway sound involves a group of participants who shared a house near to the freeway. These participants did not find the freeway sound particularly noticeable, noting that they had grown up in noisy areas and they tended to get used to the sound, in contrast they found another neighbourhood sound, which they said travelled over the freeway to them, to be much more irritating.

> Participant: ...if you listen carefully, the more distracting thing is the um, there's rowers that row up and down the Yarra, and they've got big microphones and -hear that- and they do like at 5:30-6:00 o'clock in the morning, that's the bigger issue.
> Sarah: Oh yeah, and they are actually louder than the traffic
> Participant: 100 percent, so yeah, when the traffic, when the freeway is dead quiet, you can hear them, yeah as I said 5:30 in the morning.
> Sarah: do they wake you up then?
> Participant: yeah, they wake myself up, [house mate] who's that side so he's even closer, and I can guarantee it wakes those people [neighbours] up as well.
> Sarah: and do you talk about that then? you're like kinda annoyed about that
> Participant: yeah very very, cause if it was a tradesperson or something they would be allowed to start til 7, so I don't see how that's any different.

However we note that the freeway sound was much more intense in the park than in residents' homes, and for instance when the same participants accompanied the researcher to the park they noted that they could no longer hear the rowers and that they found the freeway noise much more problematic there.

In this example we can see where the annoying sounds were attributed to human agents against whom the participants felt they had a moral complaint. Similarly participants explained freeway sound or noise as being a result of the actions of human drivers in relation to particular types of vehicles being driven and the route restrictions that were imposed on some vehicles.

For example, when listening to a sound transformation one participant noted that he could still hear vehicle braking, and as we see in the next section the noisier times of the day were also attributed to the types of driving that were associated with particular moments in the cycles and flows of traffic and how these change during the day. Another participant, commented, during a sound walk in the park:

> I can really hear trucks going past and it's quite a sort of harsh sound, it's braking and cars rumbling and trucks, like a freeway, like standing next to a freeway basically. I think it's really the car engines and the trucks are quite obvious along here, probably worse during the week, cause it's a Saturday, but I can still hear other things like that tree with the wind as well, which is really nice.

Another participant who felt he had generally got used to the sound of the freeway also noted that he hears trucks beeping their horns in reaction to being cut off in the night - rather than a general hum of traffic and this would wake him up a couple times a week. This, he said however did not bother him and he would go back to sleep immediately. However while these irritations and concerns get pushed into the background they did sometimes surface to the consciousness of participants during the interviews, as quoted in the previous section, a participant told us that 'it's also the brakes of the car, they actually you know every time you brake, there's these little particles that go into the air and fly, this is very tiny, yeah the worst'.

## Key Finding

Our ethnography demonstrated how participants attributed and explained sound and noise and the moral connotations that they attached to these sounds. Participants' interpretations of sounds tended to focus on the supposed perpetrators of these sounds, and often had a moral focus around what 'other people' do. Participants usually attributed freeway and other neighbourhood sounds to other humans, and understood them as being produced through certain activities, that they often placed a moral judgement on. It was often in relation to this that they felt a sense of annoyance, inevitability or acceptance or concern about these sounds. This is significant to keep in mind because it explains how participants interpreted freeway sound in relation to traffic and drivers and has implications for the ways that transformed sound liberates them from such interpretations and the emotions that they invoke.

## 2.2.2 The temporalities of sound

The sounds of everyday life in the home and the wider environment are usually part of our own and other people's everyday routines. Our research showed how the everyday sounds of the home involved routines of washing machines, TV watching or listening to music. Those surrounding the home and the area in which we undertook this research included the temporal changes in the freeway sounds as well as other sounds including birdsong, and the rowers mentioned in the previous section. These routines and sounds are weekly and daily.

With reference to the freeway, one participant described it was follows:

> 'Sundays are usually more quiet here, so it's probably I think maybe early morning during the week, say 6 o'clock 7 o'clock in the morning, that would be the worse I would say, other than that, yeah other times, it's only the rush hours I guess yeah, and again I think it's mainly because of the changes in noise, because they stop, it might be like traffic, it's blocked and that kind of changes in the speed it just makes more noise as opposed to something like this that it's much more consistent.'

Another participant discussed the specific ways of driving that are likely to happen at different times of the day and the impact that he imagined these would have on the sounds coming from the freeway:

> Sarah: so, it's this like a busier time for like the freeway at the moment? Is this louder than usual or?
> Participant: um it's not overly noisier, and cause its peak hour the freeway actually doesn't move as fast, so it's almost not louder, when the cars are actually moving fast, engine, brakes and stuff like that, um yeah, that's what's annoying.

### Key Finding

Participants expect freeway and others sounds to change during the course of the day and night and over the weekly cycle, according to weekly routines of work and travel. Therefore there are particular times in daily and weekly routines and cycles where sound transformation or cancellation might be perceived as more useful or desirable for both residential homes and public space. This would both relate to people's uses of public space near to freeways, as well as to how traffic noise changes temporally.

### 2.2.3 Learning and improvising to live with noise/sound

While generally freeway sound was considered to be annoying, at least initially, participants found ways to be able to live comfortably with its sound as part of their environments. This tended to involve forms of self identity and even pride at being able to live and sleep in noisy environments, ways of evaluating the benefits of the area that made freeway sound annoyances redundant, and ways of improvising in order to make the everyday environment feel 'right' and avoid the annoyance of the freeway sound.

Several participants commented on how they were already attuned to particular environments due to their past experiences (see Clip 2). For example, when one participant said that they could cope with sound due to having spent much time during their childhoods living near noisy roads and another mentioned that they had lived near an airport in the past. For example, as one participant expressed it:

> Sarah: were you concerned about the noise from the motorway when you first moved here?
> Participant: no, no I wasn't concerned, I was aware of it, but it didn't concern me, I

> used to live S___ road and there were six rails of traffic at the front so it's nothing compared to that.
> Sarah: how long did you live there?
> Participant: um 17 years
> Sarah: so, that's where you grew up then?
> Participant: yep yeah

As other participants explained, the sound of the freeway could be 'annoying' but did not have a lasting impact:

> I just find it annoying, although, you probably tune it out after a while, like I used to live next to a train bridge and every time they go over the bridge, after a while you just forget about it, you don't notice anymore.'

> 'the thing it's that after a while, I think, when you live it becomes like a background noise, that you probably don't hear as much, but I find some people are more sensitive to it.'

> I don't think about it anymore, unless someone comes over and says its loud if they come over and they stay here...then I re-think about it, oh it is loud. But then it goes away again, like when I was upstair reading a book and could hear you guys talking about it and then I was like, oh, its loud, and then I could hear it again.

In another case a participant explained how not only was he used to noise, but that the annoyances of the freeway were also somehow cancelled out for him by the advantages that the freeway brought him:

> Participant: yes, (standing at the front door) so as you can see you can hear it a lot more. Actually, if a really big truck passes, that window rattles, but once again it doesn't really bothers me that much.
> Sarah : I mean, why do you think it doesn't bother you?
> Participant: um well, because it's a massive benefit having the freeway so close, I rather a little bit of noise and be able to be in the freeway in 30 seconds straight to work than no noise and having to drive 15 minutes and then stuff like that so.

Other participants explained how they had already coped with, managed and improvised in relation to the noise and sound (as well as other sensory elements) of their homes. Closing and opening windows is an obvious, but not to be underestimated element of this, it is part of everyday routines and of the way people live in their homes. As L explained:

> First you kinda go to a rejection sort of phase, closing the windows or like pretending that it's not happening, and then you feel encouraged to do something about it, and that could be like using some earplugs when you're sleeping or something like that, then at the end you just give up and you just start to co-live with that sound, and even like it's funny, cause for me that 'noise' is I guess a reflection of a modern city, right, and there's a lot of cars that works on an engine that works on petrol and it makes noises and things like that, but I even had the experience of when I used to have a countryside house, the person who's looking after the country house he was complaining about the birds noise, so it's not only like a man-made things, it's a very personal thing, he was complaining like these birds, they wake me up early in the morning, and for me was like 'ah I love birds', it's not a thing for me, but for them it was a thing, so um it's interesting to see how everyone has a different opinion in this field, but ultimately I guess you just give up and you just get used to it, unfortunately.

clips 1 & 2 | watch

Figure 9: The open window and louvered shutters at M's house less that 50 metres from the sound wall.

In their house close to the freeway, M and his wife always sleep with the windows open, despite the freeway being only a few dozen metres away. He uses earplugs to sleep, although this was a habit he developed before moving to the area. His wife and baby daughter, however, are not bothered by the noise when they are sleeping. He explained to us how he managed the noise when he first moved to Cubitt Street:

> I think the management was more psychological - you're not going anywhere, so get on with it and see how you're going in a month's time...well this is my home, it's silly if I'm going to let road noise get in the way of this...as time goes by you talk yourself out of the fact, or into the fact that you enjoy the home and that really doesn't really bother you that much. As time went on I sort of forgot about it and I was rather sensitive to it at the start.

## Key Findings

We found participants had existing ways of getting used to or adapting to the annoyance of freeway noise, or improvising in their homes in order to be able to live with the sound in a way that felt sufficiently comfortable. This suggests that they were able to attune to this sound as part of their everyday environments, or 'block it out', particularly when they valued other elements of these environments. However, because our participants were residents of the area close to the freeway, they were people who had been both willing to move to such an environment and/or had become accustomed to the sound already. Future research would be needed to explore the perceptions and experiences, and the possible benefits of sound transformation for people contemplating moving into such areas or those who had felt that they would not wish to live in areas with freeway sound.

## 2.3. The experience of sound transformation

Figure 10: Sitting on a bench in the park was a good place to hear the different transformed sounds.
Photo credit: (Elana Vasileva-Kovac ).

### 2.3.1 The experience and generation of value through the four sound transformations

Most participants did not find the existing freeway sound in the park and in their homes/ gardens to be unexpected, and it was therefore tolerable or an annoyance to them rather than provoking dramatic reactions (see Clip 4). However the participants generally found the sound transformation possibilities to offer them a positive and desirable experience of the park, and its environment and found the idea of the use of sound transformation in this and other park contexts an appealing possibility. **In this sense the application of sound transformation technologies can be seen as a way of creating new value from existing elements of the environment that are taken as given and are tolerated or got used to but not valued.**

In this section we explain how each of the four different transformations were experienced, and which ones participants preferred. Each transformation title links to its corresponding description in the sound design report. In common we note that most of the participants did not understand the transformation process as being an actual transformation of live freeway sound before they were interviewed. Instead they often assumed that we were using previously composed soundscapes to transform the freeway sound by playing over or alongside it. Generally we found that participants concurred regarding the experiences afforded by each transformation:

#### Transformation 1: Relaxing melodic

Listen 5

Participants described the sound of this transformation as subtle and relaxing. As one participant expressed it, this sound was part of the mix of the sound in the park, something that would 'blend into the background' to make him feel calmed rather than being annoyed by the traffic, and another noted that it allowed him to hear the birds, and another that it invited him to focus in order to listen.

## Transformation 2: Microtonal soundmass

Listen 6

When discussing this transformation participants emphasised its capacity to evoke spatial qualities. They referred to it as 'echoey' something that changed 'the feel of the space around my body', and enveloping. For most this experience was questionable in some ways, and they described it in this sense as tense, intense, uncomfortable, invasive, penetrating and even sinister in one case. It was also described as 'at odds with the space', and its strangeness in this sense was emphasised when another participant referred to its 'science fiction feel'.

## Transformation 3: Seaside

Listen 7

This transformation was generally considered pleasant and to resemble a 'natural environment'. One participant used the natural metaphors of 'waves' or 'whooshing through the trees', and here the sound was seen to seep into the soundscape to fill in the gaps. One participant said that it sounded like the traffic and this person focused on trying to hear the difference, while another said it was 'too similar to the traffic noise and they merge'. Even a participant who was not so keen on this sound felt it was 'a better fit to the environment'. However the extent to which this sound was popular also depended on individual expectations or desires of the participants. Those whose evaluations were less positive related to this sound being less 'interesting', but nevertheless concurred in many ways with those of the participants who preferred this sound. For example a participant who felt it was like background white noise, at the same time told us that 'I feel it cuts it all and blends [the road noise] ...it evens it all out a little bit' and another felt that they would not notice it if it was in the park.

## Transformation 4: Pan-diatonic soundmass

Listen 8

The final transformation was understood by participants as being more complex and they more often emphasised that the felt this was composed soundscape, or piece of music. One participant imagined that the traffic participated as a small part of this composition. In relation to this they said that it reminded them of a combination of natural and musical sounds, such as: it being flowing, moving the breeze and the trees; wind chimes; chanting and bells; it sounded musical; and it was uplifting. Participants also noted a sense of 'resonance' the idea of being underwater, said the sound was calm/calming, relaxed and immersive. Generally participants had a positive experience of this sound transformation, while one participant felt that it imposed sound on him.

### Key Findings

Participants tended to concur in relation to the experience of each sound transformation. In general they were in favour of sound transformation as an enhancement of the experience of the park in relation to traffic noise. Sound transformation was appreciated for its 'natural' feel, and often understood as a composition rather than a live transformation.

Sound transformation involves a process of creating value out of something that was previously an annoyance. The value or potential value of sound transformation lies mainly in its capacity to create more pleasant versions of existing annoyances, and to make relaxing, and calming environments.

### 2.3.2 The experience of sound cancellation

Fewer participants engaged with the sound cancellation experiment, however those who did found it interesting and in some cases an 'amazing' experience. They felt that this would be a valuable experience to make available in specific locations where there was a particular noise annoyance, or where a specific experience was desired.

**Key Findings**

Sound cancellation was appreciated as a valuable experience that could be potentially offered in site-specific contexts.

## 3. Implications

### 3.1. The appeal and wellbeing benefits of sound transformation

What is most striking about the sound transformation experiences is the way that participants were able to feel attuned in different ways to the transformed freeway sounds. There are three key points to consider here:

- Freeway sound was considered by participants to be 'normal' and if anything annoying, but not dramatic. Therefore, when they were listening to freeway sound transformations, participants were experiencing another rendering of a sound that they have already acquired some degree of attunement to, or that they have come to consider familiar or normal in their lives. This is significant because it indicates to us how freeway noise is in fact a form of everyday sound that people already have a relationship too. Once it is transformed - that is, it is made pleasant, rather than annoying - people find it easy to feel comfortable with. This research suggests that this is because they are already used to this sound and attuned to it. However because in its usual form (as freeway sound) it is perceived culturally and actually experienced as annoying, then it is not valued. By transforming something that people already relate to into something pleasant, the process of transformation creates value in new and surprising ways, and importantly it creates value were it did not previously exist. **The role of sound transformation in producing new forms of value is highly significant.**

- Participants understood most freeway sound as being the outcome of other human activities and reactions to traffic or road conditions and as being related to the driving of particular types of vehicle. While there was sometimes a moral dimension to their judgement about people making noise, the fact that they interpreted freeway noise in this way emphasises that the sound of freeways is something that emerges as an outcome of relationships between humans, technologies (vehicles) and environments (road conditions, weather and the built/natural environments around the freeway). When people hear freeway sounds they are therefore listening to this relationship, and it is indeed one that as humans they can also relate to. In this sense it should not be surprising that when participants listened to the transformations they often assumed they were composed and already recorded pieces, when in fact they were listening to live transformed sound. **The musical qualities and compositional elements they thought they heard are important to keep in mind since this means that**

**people interpreted a resonance between the human-technology-environment relationship that driving entails and musical, calming and relaxing soundscapes**

- Participants valued transformed sound, and the research suggested that it had a 'special' quality. It would enhance everyday experiences in ways that participants identified as bearing a relationship to existing everyday and special moments: listening to music or other sounds; relaxation; a calming effect. **Sound transformation makes value out of the environment around us and therefore plays an important role in recycling those elements of the environment that are not desired and creating new value from them, as elements of everyday life that are seen to generate forms of wellbeing.**

Key Findings

Together these three points demonstrate that because sound transformation creates new value by transforming existing annoying but nevertheless familiar elements of the everyday into pleasurable ones, it has the potential to generate new forms of wellbeing on two levels: it first pushes into the background the elements of everyday sounds that are annoying, as well as the feelings, values and judgements that make these annoying; and it second, creates localities and experiences in everyday life that generate senses of wellbeing, calm and relaxation.

## 3.2. Future possibilities for soundscape design through sound transformation

Our research implied various different future possibilities for sound transformation soundscapes. We note that these tended to be based on participant experiences of sound transformations in the park however, and in order to develop a fuller future-focused project a specific future-anthropologies methodology would need to be designed.

- Transformed sound might not be needed at all times or in all localities. Moreover different people may have different needs at different times of the days. This invites the possibility of people moving in and out of small pockets or fields of sound during the day or during a park experience, according to human need - for instance to be in a silent space, or with a calming soundscape. For example, one participant mentioned an example of existing park soundscape installations overseas where particular noises could be heard in localised areas. Sarah asked him: 'So, would you like it if it was here if you could hear it in certain places and others not?' to which he explained 'Probably yes, so you could choose if you are in the mood to sit on a bench and enjoy the music and just the sky or if you prefer to'. He emphasised the need for the sound to fit the mood and activity, speaking of one of the transformations he noted that: 'probably if I bring my kids with a ball, this music, it's not to play'.

- The physical surroundings, weather and activities of other people played a role in how participants envisaged possible future experiences of sound transformations in this and other parks. People use the same public space for different things, although broadly related to amenity, specifically relaxation, exercise or play. Could relaxation, exercise or play be designed into sound transformation installations more explicitly?

There are also future possibilities to consider the role of sound transformation in smart and IoT environments. Here, it would be important to gain an understanding of how people will benefit from and engage with sound transformation experiences in smart/IoT contexts.

This would enable new insights into how environmental sensor technologies connected to sound transformation technologies could be engaged for automated or semi-automated

Recommendation: To consider and test how sound transformation experiences would best be brought into public space in ways that will optimise their beneficial effects to the public; and to similarly investigate how and where they would benefit domestic space in residential areas. Further to this to develop sound transformation technologies with an eye to how they might become automated in relation to sensor technology data and user community data produced in smart or other digital city configurations which will enable their temporal rhythms to follow those of citizen's everyday life experiences.

## 3.3. Future research needs

This ethnographic study has enabled us to develop an initial set of key insights and knowledge regarding how freeway sound is experienced in different residential and public contexts, and how sound transformation experiences can transform it into a valuable resource for the generation of forms of wellbeing in everyday life contexts. This project has also demonstrated the effectiveness of an ethnographic methodology in producing new insights and knowledge about the experience and potential benefits of sound transformation. However the research reported on here is site-specific and also targeted residents of a popular and desirable residential area in Melbourne, and we strongly recommend that any further installations of sound transformation technologies be accompanied by in depth ethnographic research in order to enable an evaluation of the needs of residents and visitors in terms of:

- Existing sound experiences of local residents in home and users of and visitors to public space
- The locations of sound transofrmation experiences
- Timing and temporalities of transformation experiences
- Testing a series of different transformation experiences ethnographically with participants over time to gain an understanding of site specific transformation experiences, how and why these are most valued, and the ways in which forms of wellbeing are generated through them and when they are not

Recommendation: To develop further ethnographic research that builds on the findings of this study, and is developed in collaboration with sound transformation design research, in order to ensure that future installations are site and user-appropriate.

## References

Pink, S. (2015) Doing Sensory Ethnography. London: Sage

Pink, S. and J. F. Salazar (2017) 'Anthropologies and Futures: setting the agenda' in J. Salazar, S. Pink, A. Irving and J. Sjoberg (eds) Future Anthropologies. Oxford: Bloomsbury.

Smith, R. C., K. T. Vangkilde, M. G. Kjaersgaard, T. Otto, J. Halse, T. Binder - (2016) Design Anthropological Futures. London: Bloomsbury.

Ingold, T. 2000. The Perception of the Environment. London: Routledge.

Ingold, T. 2010. Being Alive. London: Routledge.

Geurts, K. L. 2003. Culture and the senses: Bodily ways of knowing in an African community. Berkeley, Los Angeles, London: University of California Press.

# Urban Design

MDIT studio with research team at the Epping, Sydney site.

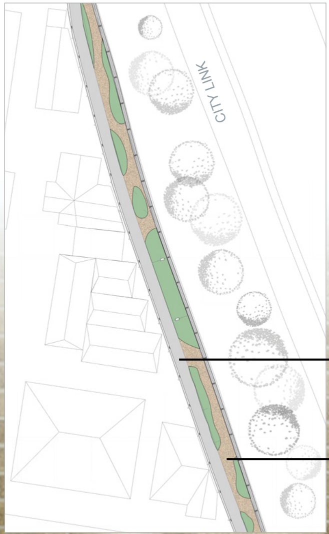
## Studio Summary

Eleven students from the RMIT Master of Design Innovation and Technology (MDIT) were part of a studio that researched ways that the successful noise transformation methodology might be applied as an urban design solution to parklands adjacent to motorway noise walls. Students were given the unique opportunity to engage with the researchers during the Sydney-based test site installation, during which they could hear the noise transformations in-situ and liaise directly with the researchers.

They were asked to design a fully landscaped motorway parkland that embedded electroacoustic infrastructure into a noise wall. The primary intention of the designs is to encourage local residents to utilise the parklands as spaces of play, recreation and imagination.

During the design sessions three motorway noise wall parkland typologies were recognised: the corridor, the wedge and the field. The studio was split into three groups, with each group assigned a typology. The following section includes the designs, which incorporates feedback from the research team, Transurban and VicRoads personnel, presented on April 21 2017.

These designs should be viewed as real opportunities for future infrastructure projects.
Full presentations can be found on the companion website.




## Typology 1 | Corridor

### Tranquil Transitions

A primary feature of the corridor typology are houses built very close to an adjacent noise wall. Sound reflects between the hard surfaces, which increases the overall sound level. These spaces are often devoid of proper vegetation, making the landscape feel ‘hard’ and uninviting. Our design strategy aims to soften these spaces with interventions that invite people to play in an interactive sound park. Green mounds, made of artificial turf, create a meandering slow path that encourages passers-by to slow down and immerse themselves in the transformation soundscape. Children can add to the soundscape by calling into hidden microphones. On the adjacent path a moss pattern plays with the cyclists visual perceptions of speed. T-capped noise walls are designed to increase overall attenuation.

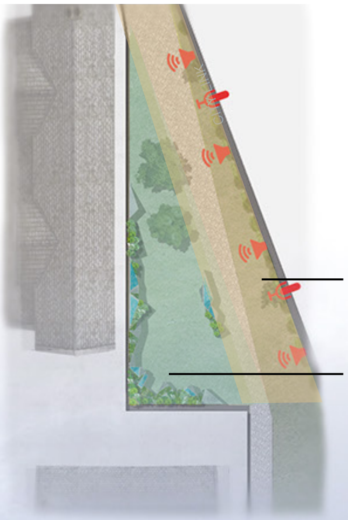
***Fast Path***

Designed keeping cyclists in mind.

***Slow Path***

A meandering path encourages passers-by to slow down and immerse themselves in the soundscape.

Leixin Du
Ben Sahadan
Komal Lakhanpal
Michelle Suprapto



## Typology 2 | Wedge

### Water & Herb Garden

Sound transformation aims to create positive perceptual changes for communities adversely affected by traffic noise. Speakers are installed along the top of the noise wall to give transitioning pedestrians and bicycle riders a unique sound experience. On the far side of the wedge water and vegetation augment the transformed soundscape to induce positive emotive responses, which focus on the auditory and olfactory senses. The stacked structure and seating edges give users an intimate feeling in which they are encouraged to stay and enjoy the peaceful environment.

***Transition Area***

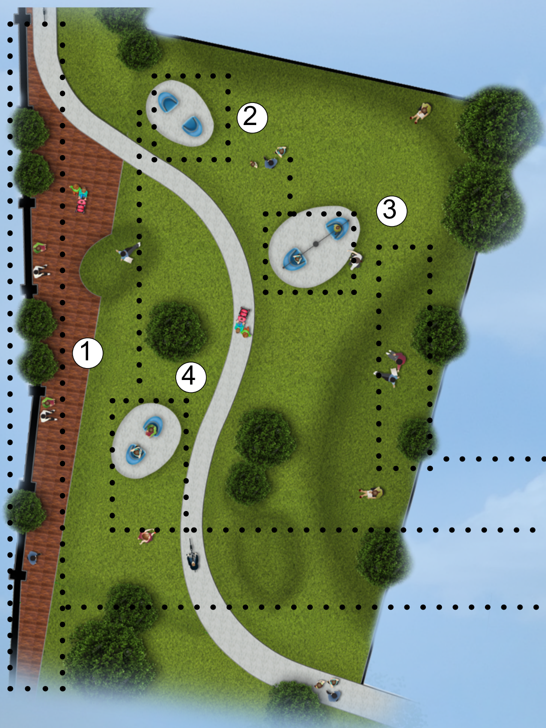
Creepers on the noise wall soften the environment and discourage graffiti.

***Intimate Area***

Waterfalls and herb gardens aim to encourage people to enjoy some reflective time in the park.

Jiayi Liu
Qianying Yang
Yunkai Zhao

**Typology 3 | Field**




## Sonic Playscape

We have designed for the augmented sonic realities created by noise transformation. Since the site is part of a close-knit community, and is located near a school, we decided to focus on creating a playful environment. The transformed soundscape fades in and out at different parts of the park, depending on the mobility and distance of the user. We have taken advantage of the open spaces of the field typology to create a range of user experiences. We have provided for those that transition the space, and those that remain to enjoy the play equipment and seating areas.

***The Wall*** : A soft surface is added to the noise wall to improve perceptions of the environment. The second noise wall surface provides a seating area for parents while they watch their children play.

***Play Instruments*** : Children can play on interactive play equipment that creates soundscapes through interaction.

***ZONE 3***
Space for relaxation

***ZONE 2***
Interactive play equipment for children

***ZONE 1***
Space for parents and the elderly

1. ***The Wall***
2. ***Rocker***
3. ***Hanging Circles***
4. ***Rotating See-Saw***

Rui Xue
Prabhnoor Kaur
Awnili Shabnam
Sree Padma Marthi