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A Framework for Improving Urban Soundscapes

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Abstract

Sound in public urban spaces is often considered in negative terms as both intrusive and undesirable – it's referred to as noise! However, this issue is multi-facetted and goes much deeper than simply reducing levels. There are many positive aspects of a soundscape.

In an attempt to progress thinking on positive soundscapes and move towards more practical planning approaches and decision making tools for soundscape assessment, this paper proposes an approach traditionally used in product development and manufacturing quality – The Kano Model. The approach is captured in the form of a broader framework which covers: the composition of a soundscape in objective terms; the factors affecting whether it might be perceived as positive; and how the Kano model for product development can be used as a means of understanding the range of applicability of approaches to create positive soundscapes (including several novel approaches which are the subject of other papers in this issue). It can be considered to be complementary with previous frameworks, some of which have concentrated on sound sources, others on the factors affecting perception or even as a model for understanding individual evaluation. In this case the motivation behind the framework is to help assess the likely impact of practical interventions on the positive aspects of a soundscape.

The framework proposes that the meaning of "positive" for a public space is quite different for three types of people, each with a different level of direct engagement with the soundscape: planners; serious listeners; users of the space. The first two are influenced by the soundscape itself, either in meeting legislation and reducing nuisance, or as an artistic or creative opportunity. However the third, arguably most important group of people, users of the space, are more concerned with the space itself and have their perception of it influenced by the soundscape, which is an inconvenient and highly complex intermediate step. This influence is largely determined by their activity e.g. reading, holding a conversation, shopping or sightseeing.

The paper discusses the further implementation of the framework, and how barriers to the wider application of the concept of positive soundscapes might be overcome. It shows how adapting an approach previously used in automotive sound quality can be adapted for urban soundscapes. It concludes with recommendations for taking the framework forward as a practical approach.

Keywords: Soundscapes Framework, Planning, Sound quality, Activity-based, Emotional dimensions

1. Introduction

Sound in the environment has traditionally been considered in negative terms as both intrusive and undesirable – even the term noise gives a negative impression. Consequently, much of the relevant work to date has been oriented towards engineering noise control and determining which sound sources planners should aim to limit. However, this multi-facetted issue goes much deeper than simply reducing sound (or noise) levels. The auditory landscape, commonly known as the

soundscape, has many positive aspects. For example, the sounds of running water, such as from fountains, are often high in level (for example, measured in dB[A]) but in some cases can have a soothing quality. They can also be used to effectively mask other irritating sounds. Traffic noise can be annoying, but the sound from individual vehicles can provide positive information, a warning, to pedestrians about their presence. The state of the listener is also important – sounds which may be described as intrusive or disturbing by a listener who is reading a book or holding a conversation could be described as interesting by another listener who is shopping or sightseeing.

Ideally, planners, architects or engineers need to be able to assess the likely impact of different design alternatives on a place's soundscape. This will allow them to make a more confident decision or choice based on all factors (such as cost, visual aesthetics, sustainability etc..), and including a proper consideration of the impact on the soundscape. For them to be able to do this, they need to be able to clearly understand the complexity of the problem, and also the relevance and applicability of the variety of tools, methods and concepts that researchers have developed over recent years. I.e. a simple underpinning framework is required.

This paper introduces such a framework, which attempts to link design interventions to the likely impact on the perception of a space. To provide a new perspective on the problem, the framework's novel approach is to use the Kano model – an approach traditionally used in product development [1] to help classify the different types and levels of design choice or intervention, and ***accepts that in most cases the soundscape itself is an inconvenient and highly complex intermediate step.*** This is because for most users of a public space, their primary activity and interest is something other than listening to the soundscape. The framework is structured in three parts which:

- describe the elements comprising a soundscape (part 1)
- account for the many factors that can influence whether a soundscape is perceived as positive or not (part 2)
- link any design intervention on the space itself to the likely effects on the perception of that space (part 3)

This framework is intended to help stakeholders embrace the concept of positive soundscapes and to encourage them to think differently about sound in the environment. It is also intended to help facilitate their greater involvement in the development of new decision making tools. The appropriate choice and use of such tools will also be linked to the types of intervention classified by the Kano model within the framework. Furthermore the framework embraces both noise solutions based on legislative requirements, and at the other extreme, the creative approach of sonic artists, showing their respective roles.

It should also be noted that the motivation for this framework is in the improvement of soundscapes and the assessment of different interventions, however it can also be used to understand the role of new techniques for evaluating existing soundscapes, such as soundwalks [2]. Furthermore it can be treated as complementary to previously developed frameworks, some which have concentrated on sources [3], others on the factors affecting perception [4] or even as a model for understanding individual evaluation [5].

Having introduced the framework, the paper goes on to discuss its potential application and how learning from the automotive industry, where a similar approach has been successfully used in the creation of positive sounds for cars [6], might be adapted for its fuller implementation. The need for further research and development on tools and methods is recognised and also the fact that planners should ideally be able to take holistic decisions, balancing the impact on the soundscape

of any design intervention they make, with potential impacts on other aspects of the environment such as safety, air quality and sustainability. Finally, recommendations for the further work needed to validate the framework through the creation of a body of experimental evidence are discussed.

2. The Composition of the Soundscape (Framework: Part 1)

Most engineering targets are set using numbers. However, a soundscape cannot be described by traditional numerical metrics alone. Soundscapes can have the same measured levels, but can be perceived very differently by listeners. Many research studies have commented on the independence of level and perception of a place [7,8,9]. This is because, amongst other things, level does not include consideration of character and it also does not account for the levels of neighbouring areas with which the place might be positively or negatively compared [10].

Even psychoacoustic metrics such as loudness, roughness, articulation index etc, while useful for describing the human response to a sound signal [11] from a single source or simple product, cannot describe the perception of a soundscape in full. A soundscape is made up of multiple, often time-varying [12] sound sources, and is also affected by the relationships between those sound sources in time and space.

Figure 1 presents this concept visually, where "Sound" represents traditional objective measures of the sound signal (such as psychoacoustic metrics like loudness, sharpness etc) and "Scape" represents the concept that a soundscape is a dynamically changing entity, made up of various sound sources, the perception of which also depends upon the variety, mix, direction and interplay of these sources. There are many ways of describing the factors that make up the "Scape". Some possibilities are shown in Figure 1, though it should be noted that these are illustrative and not exhaustive.

However this approach to describing the composition of a soundscape is based upon a requirement for an objective and repeatable assessment of its composition, and recognises that there are features relating to its total effect and to its individual components. Other features, that are dependent upon the listener or the place, are included within other parts of the framework. This approach can also be seen to be complementary to other approaches to classify soundscapes, such as Schafer's use of keynote, sound signals, soundmark, lo-fi and high-fi [13] which is commonly used in case study examples.

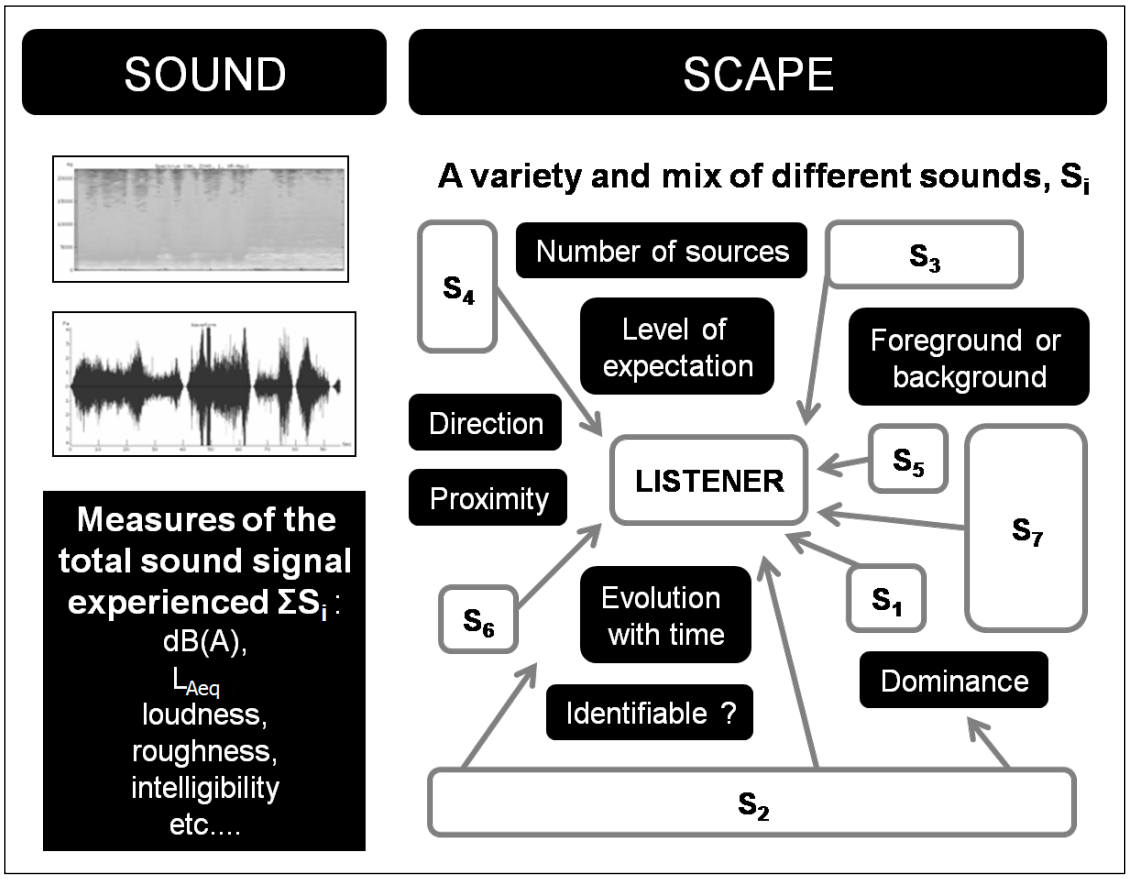

Figure 1: Framework Part 1 – Sound-Scape

It can be seen that that even the description of a soundscape is complex. However the question being posed is "what is a positive soundscape ?" or more importantly "how can decision makers learn if a particular design intervention will result in a more positive soundscape ?". This question has been stated as a comparison for two reasons. First, most practical interventions will result in changes to an existing space, with an existing soundscape. Second, it is easier for non-expert listeners to make relative judgements from listening to two soundscapes, rather than an absolute judgement on a single soundscape.

3. Factors affecting Positive Perception (Framework: Part 2)

It is widely acknowledged that certain individual sounds such as birdsong and running water are perceived to be pleasant, whereas traffic noise is generally perceived to be unpleasant. However, "pleasantness" can only be judged in context. The sound of water, although sometimes considered pleasant, might become annoying if it is at such a level that it intrudes on a conversation or mobile phone call. The sounds of street musicians may be annoying when travelling to work, but could be quite enjoyable at other times, or vice versa? The perception of a soundscape is inherently personal and affected by what a listener, each with a unique set of experiences and preferences, brings to the listening situation.

This framework is therefore underpinned by the proposition that a person's perception of a soundscape depends most strongly on the activity they are doing at the time, and consequently their corresponding state of listening. Truax [14] defined three states of listening:

- **Listening in search**, or analytical listening - an active, conscious activity where the listener is "tuned in" to whatever they are listening to. e.g. concentrating on listening to birdsong.
- **Listening in readiness** - an intermediate type of listening where the listener's attention is ready to receive significant information but where the focus of attention is directed elsewhere. e.g. recognising your own phone ring, when others' phones are ringing around you.
- **Background listening**, or distracted listening - where the listener is engaged in another activity, "tuning out" the sound e.g. concentrating on reading a book or holding a conversation.

These listening states could be mapped onto the various activities that can take place in urban spaces [15]. Therefore finding the answer to what is positive sound for the user of an urban space, starts by adopting an activity-centric standpoint. Figure 2 summarises this and the other main influences on the perception of a soundscape:

- Activity - why the listener is present in the place, and how they are listening
- Demographics - who they are
- Time - when they are listening and for how long
- Space - the location, use and physical characteristics of the space itself

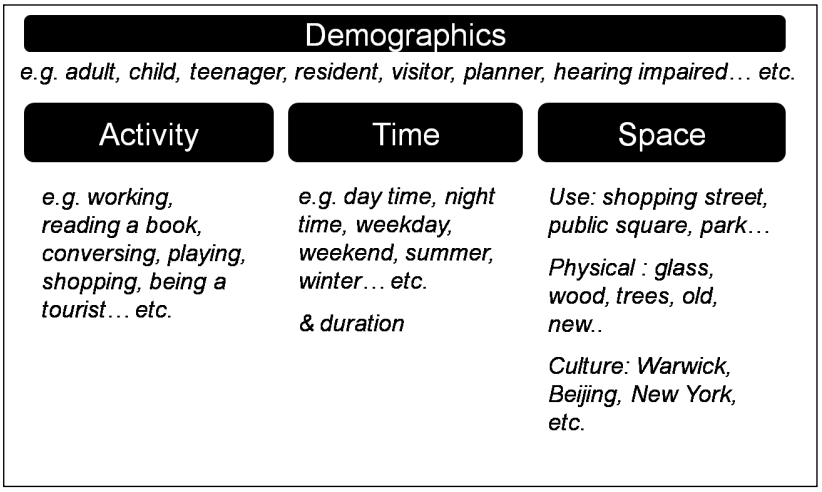

Figure 2: Framework Part 2 – Factors affecting positive perception

In summary, to understand what is meant by a positive soundscape, it is necessary to relate "positive" to activity, and to accept that different types of people carry out different activities at different times of the day/week/year for different durations in different types of urban spaces with different characteristics in different geographical locations.

These factors all affect the perception of soundscapes, but interestingly, **few of them directly relate to the sound itself**. However presenting them in this way allows us to clearly identify and understand all of the influencers on soundscape perception. The listener demographic can affect the

perception of a soundscape [16] according to measurable factors including: age; gender; and impairment (visual or hearing). Furthermore, the status of a listener as a visitor or a resident could also have an effect since a person's priorities and responses may be different according to this status. In addition to the objective demographic indicators, people also bring their own cognitions to the listening situation. These cognitions can represent memories, ideas, feelings, attitudes, values, preferences, meanings and behaviour and experience which relate to the variety and complexity of the physical setting [17,18,19,5].

It is also important to consider the effect of temporal conditions [12], as perception of a soundscape may change over the course of a day, or over the course of a week or a year. Weekdays and weekends may produce very different soundscapes in the same space. Seasonal differences, and consequently changes in the weather also have a significant impact. The purpose of a specific type of space, i.e. whether it is a public square, thoroughfare, busy road, undercover shopping area etc. will also obviously affect the soundscape, as will its geography, culture, morphology and the built landscape, so it is important to take all of these factors into account.

Furthermore, and most importantly, demographics, temporal conditions, and the type of space all indirectly influence the type of activities that are most commonly being pursued within that space. For example, children occupying a town park in the summer are likely to engage in different activities to pensioners in a shopping street in winter!

Given the breadth and complexity of these factors, it is proposed that understanding the activities being carried out in a place is crucial (and, most importantly, feasible), when assessing the effect of potential interventions on the place's soundscape.

4. The Impact of a Design Intervention on Perception of a Space

For those people involved in the design or development of a public space be they planners, architects, engineers or other stakeholders, they are often faced with the challenge of assessing the relative impact of any design intervention they might make. For example, they could be considering different traffic layouts in a public square, the use and choice of acoustic barriers or the potential design and positioning of water features. In some cases they might need to decide if a particular soundscape was of significant interest and required preserving [20].

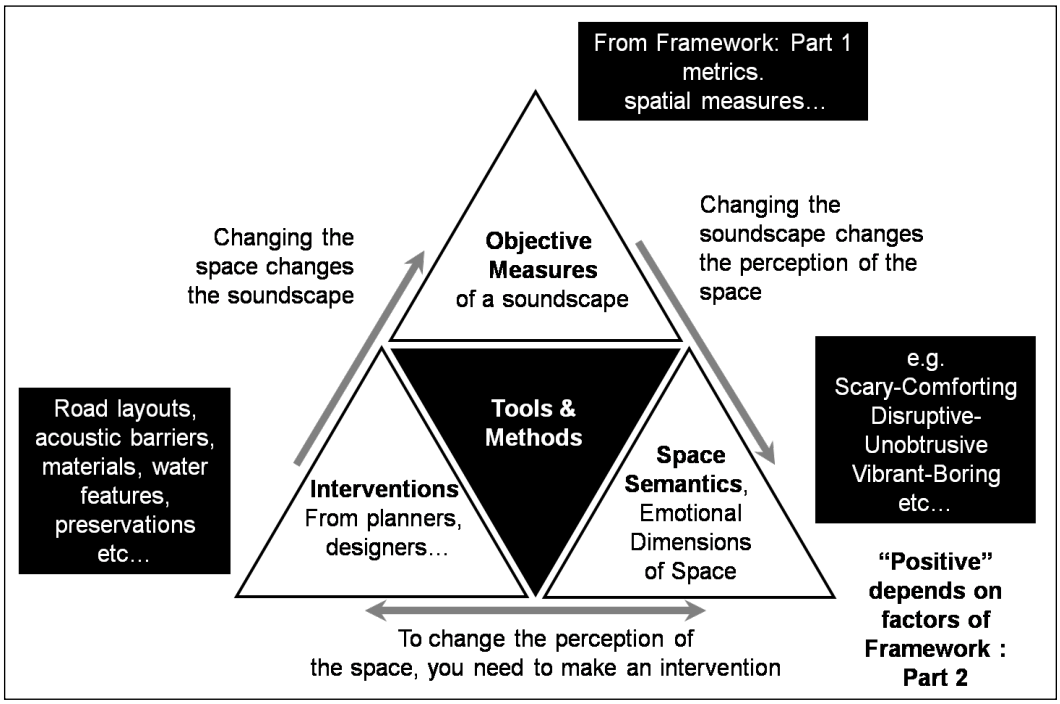

Figure 3: Assessing the impact of an intervention

By making an intervention and consequently changing the space, the first effect will be a change in the soundscape itself. This can be quantified by measuring changes in the sound field itself as experienced by an occupant of the space. This will have the two elements as described in part one of the framework – those measures associated more with the signal and those associated more with spatial measures i.e. the mix, positioning and interplay of the various sources.

However, as described in part two of the framework, for most users of that space, the major impact of the design intervention will be dependent upon their activity – they will not be specifically listening to the sound. The authors propose that it is important to focus on the potential resulting change in perception of the space as shown in Figure 3 – for example, as a result of an intervention, the space might now be more interesting, comforting or vibrant or maybe spooky, obtrusive or dull. A soundscape is therefore considered positive if it enhances how people feel about the place.

This is important in that previous research attempting to classify positive features or "dimensions" of a soundscape has often combined descriptors of the soundscape, the sounds, the sound sources and the place. In this framework, any intervention or design alternative can be compared in a consistent manner i.e. the likely impact on how people feel about the place.

So far, the emphasis has been on understanding the listening experience, in particular that of the everyday users of the space. However there are two other groups of people who have a strong interest in the soundscape, but who needn't be regular users of the space:

- those with a responsibility for the noise control of the space i.e. planners who need to ensure compliance with any legal requirements and noise controllers whose responsibility is to control noise nuisance.

- those who have an active interest in soundscapes for their own sake, for example sonic artists or people concerned with conserving soundscapes of cultural significance.

This is illustrated in Figure 4 which shows this broader range of stakeholders and their relative levels of direct engagement with the sounds of the soundscape. The least engaged are the "noise controllers" who may not even visit the space, but are solely interested in legal compliance. There are then the main group of people, those who normally use the space for a variety of activities and who are more or less willingly engaged with the soundscape. Finally there are those people who deliberately wish to experience, record or even contribute to the soundscape – here called "serious listeners".

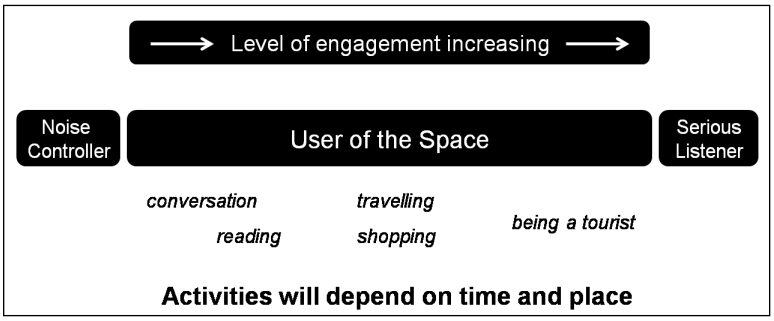

Figure 4: Direct stakeholder engagement with soundscape

5. Application of the Kano Model (Framework: Part 3)

Due to the complexity of the perception of soundscapes and the diverse perspectives of the various stakeholders, a single approach to assessing interventions is therefore not likely. In fact a variety of approaches should be considered. In order to consider how the best and most appropriate tools might be chosen, and their relative priorities, a manufacturing quality view often used in automotive engineering, the Kano model [1], might help to clarify thinking. This model is used to focus on the customer perception of the quality of a product or service, and to focus on the relative importance of attributes or functions.

A typical Kano plot is shown in Figure 5. The horizontal axis indicates the degree to which an aspect of the product or service is present. The vertical axis shows the level of satisfaction of the customer or user. These aspects are split into three categories :

Performance – often called satisfiers. These requirements behave one dimensionally – a "more is better" or "less is better" mentality. For example for a car, fuel economy is one dimensional.

Basic – or must-be requirements. This type of requirement behaves very differently. Absence leads to dissatisfaction, but the presence of that attribute doesn't move satisfaction above neutral. For example a car's starter - a poor or unreliable starter leads to dissatisfaction, but a good starter doesn't increase satisfaction.

Excitement – or attractive requirements – those, usually unexpected, aspects of a product or service that might delight a customer. Absence of them does not generate dissatisfaction, but their presence increases satisfaction. For a car, at the moment, this could be heated seats or a slick satellite navigation system.

In the formal usage of Kano's methods, questionnaires and other tools are used to categorise the various aspects of a product or service.

To use a sound analogy, for automotive application, it can be postulated that basic features include the absence of squeaks and rattles, performance would relate to interior sound level and excitement would be represented by current research on sound quality. When a driver accelerates hard, they may have a feeling of excitement from a satisfying "roar" from the powertrain. Extensive research has been carried out to enhance these positive features and some of the relevant learning generated to achieve this will be mentioned later.

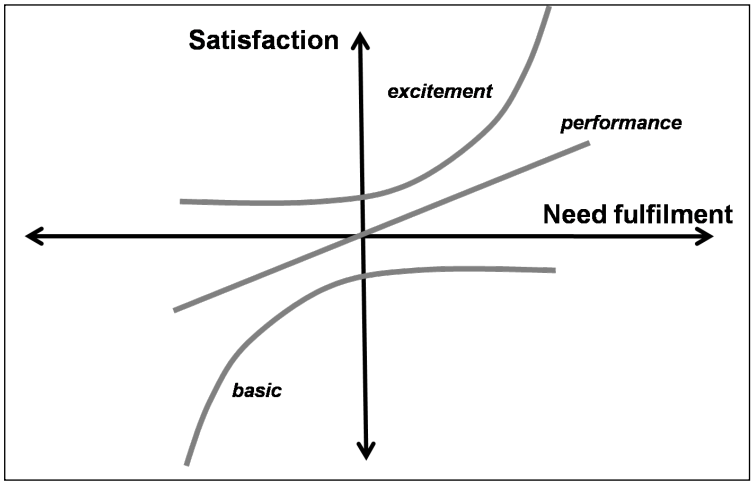

Figure 5: A Kano plot of product or service requirements

Returning to Figure 4 which shows the level of engagement of different stakeholders, it is suggested that the requirements of the soundscape of a public space change from basic to performance to excitement as the level of engagement with the sounds increases, as shown in Figure 6. Also illustrated is the fact that for the basic and excitement requirements, it is indeed the soundscape that is the focus of the evaluation, but for possibly the most important requirement – performance, it is the perception of the space that should be the focus of the evaluation. Noise controllers are purely interested in eliminating nuisance and complying with legislation. The tools they require should be simple and numerical – they just wish to see that the soundscape is the right side of a simple measurable threshold, a basic quality.

At the other extreme, serious listeners are interested in identifying, creating and preserving soundscapes of significance – those that provide the excitement requirement. Relevant interventions here should allow creativity and could include the introduction of interesting or even culturally significant sound features.

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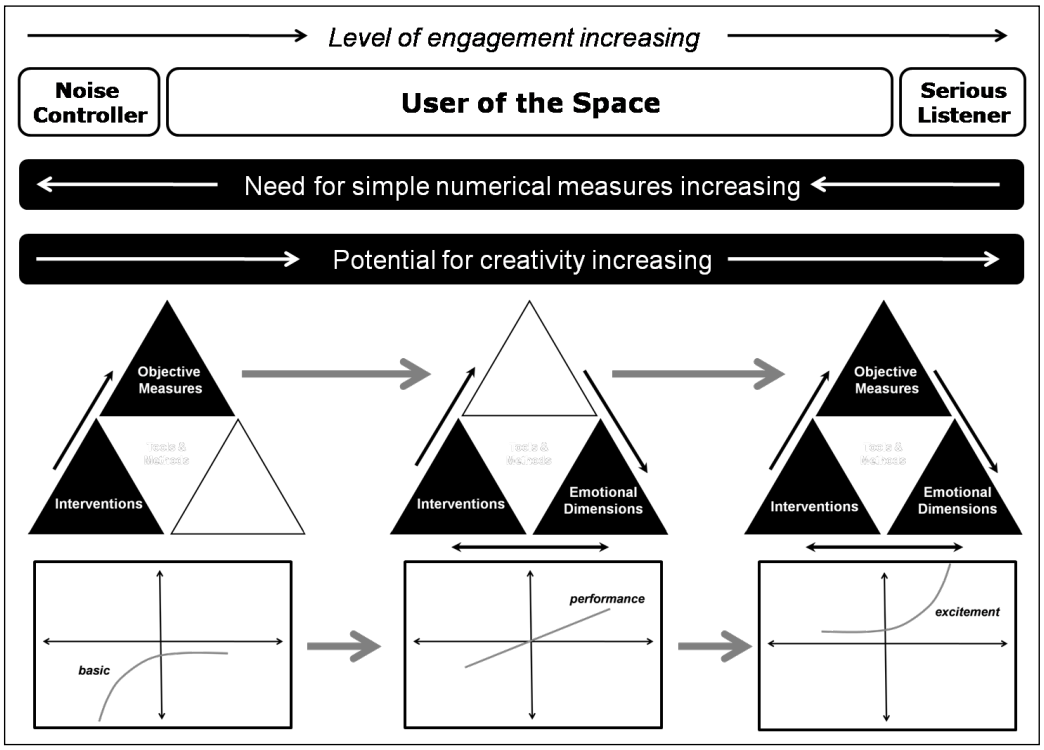

Figure 6: Framework: Part 3 – mapping Kano attributes onto levels of soundscape engagement

6. Implementation of the Framework

The Kano model highlights the order in which soundscape evaluation should be considered. The first step is to consider basic requirements, assuring compliance with legislative requirements and eliminating noise nuisance. Assuming that the basic requirements have been satisfied, it is the performance requirement of the soundscape, that affects the different types of activity of the users of the space, that needs, and has most potential for, a new approach to decision making. For this application, new methods could be embraced, such as the use of emotional perceptual dimensions and interactive simulation. Furthermore new techniques for evaluating existing soundscapes and for engaging users and capturing their perspectives, such as soundwalking, play a role here.

It is also potentially useful to see what approaches could be learned and adapted from automotive sound quality where it is already accepted that a lower level sound isn't necessarily a better sound [6]. Furthermore tools and methods have been successfully developed to understand "what are positive car sounds ?" and to allow engineers to create them. In a similar manner, those people who can influence the design and interventions for public spaces need to be able to understand how any decision that they might take, could affect the perception of the place, through a change in the soundscape.

It is accepted that in several respects, automotive sound quality is a simpler case. For car manufacturers, activity considerations are simpler – for interior sound, the listener is either driving or travelling in a car. Furthermore the motivation for a manufacturer is to sell more cars, whereas even identifying the key stakeholders in soundscape evaluation tools is not straightforward. For example, are they architects and civil engineers who wish to offer a differentiating capability in the

service they provide, or local authorities who wish to provide better public spaces ? Despite this simpler scenario, the overall aims are still sufficiently similar for much to be learned.

In order to progress this, research is ongoing to allow stakeholders to use two of the most widely used techniques for automotive sound quality :

- *Target setting and benchmarking based upon perceptual dimensions.* This involves understanding the language of users i.e. identifying the independent dimensions/feelings about the space that can be affected by changing the soundscape. Through conducing a Principal Component Analysis, these perceptual dimensions can be reduced to a simple two dimensional graphical representation, with one dimension on the x-axis and another dimension on the y-axis. A specific study to define the principal emotional dimensions of a soundscape is reported by the authors in a separate paper within this issue [21], where it was proposed that "calmness" and "vibrancy" are the key emotional dimensions of an urban soundscape. The study went on to show how through listening studies, current and potential future soundscapes can then be compared on a scale based upon these positive dimensions, allowing target setting for proposed soundscapes and the benchmarking of existing soundscapes. The study showed how introducing interventions such as traffic, church bells and water features into a soundscape could change listener perception of the calmness or vibrancy of the space.
- *Interactive simulation*. There is no substitute for listening to representative sounds and soundscapes when discussing options. Consequently interactive simulation where stakeholders can listen to alternative sounds and soundscapes (created based upon different design or planning alternatives) in an interactive, controlled and repeatable environment with some appropriate context, already successfully used to engage decision makers in automotive manufacturers [22,23,24] could play a useful role. In the context of soundscapes, such systems are already in development [25]. Furthermore, investigations have shown the influence that vision has on audio [26] (and vice-versa [27]) so it is important to take into account the visual domain in interactive simulation too. Given the huge number of variables and unknowns for a soundscape, it is accepted that a similar accuracy could not yet be obtained for an artificially created soundscape as for interior vehicle sounds. However given the large number of variables and the time varying nature of soundscapes, the ability for decision makers to experience a range of alternate soundscapes as a result of different design choices is still considered potentially very powerful. Guidelines could be created, based upon different types of intervention for different types of urban place, a measure being the likely effect on the emotional perceptual dimensions, calmness and vibrancy. Similarly it would be possible to use interactive simulation in structured evaluations, and in discussions with the public.

Beyond the performance requirement, and a new focus on the impact on users' activities, the creative aspect of soundscape design (an excitement or attractive quality), should also be considered. The introduction of culturally significant sounds, or sonic art could add significant value and help to differentiate a public space, and give it a unique character. It is important that any new approach to positive soundscape design does not lead to many similarly sounding spaces, with the loss of excitement for the more serious listener. This is similar to the case with automotive manufacturers, where as well as engineering sounds suitable for a particular type of vehicle (e.g. sports car or luxury saloon), they wish to differentiate their brand from competitors.

As well as the ongoing development of new tools, there are other means by which positive soundscapes could be encouraged to be more widely embraced within planning processes:

- *Links to health and wealth creation should be made more explicit.* The negative impacts of poor soundscapes on health are relatively well established. These include reduced sleep, stress and reduced cognitive abilities [28,29]. However, the concept of positive soundscapes, and for example understanding how to increase the vibrant feeling of a space, could lead to benefits for retailers and other businesses. Similarly a more calming place may attract people back to our city centres. These impacts could then be the opposite to negative soundscape effects, such as high noise promoting higher walking speeds [30] and reducing people's willingness to help others [31,32].

- *Soundscapes should be part of a holistic view on the environment*. The consideration of positive soundscapes within planning could be integrated into a more holistic treatment of the different potential environmental impacts of an intervention. For example, transportation noise, one of the pervasive sources of environmental noise, should be considered in the context of global CO_2 reductions, and local air quality too. New vehicle powertrain technology, which is often optimised for attributes such as performance or economy, will also affect soundscapes. Ideally we should be considering the impact of new transportation and infrastructure on noise, local air quality, safety and global carbon emissions all together. For example, speed bumps, though good for slowing vehicles down, can have a detrimental effect on emissions and noise, due to the consequent decelerations and accelerations. The move to plug-in vehicles could have benefits for all types of emissions (remembering that carbon emissions need to be considered as well-to-wheel, not tank-to-wheel) but at present carbon emission and noise emission benefits are often presented and discussed separately. Furthermore the sound of future individual electric vehicles will ideally need to be optimised for: safety with respect to other road users, primarily pedestrians; their impact on urban soundscapes; and the effect on the brand perception of the manufacturer. This will provide a significant challenge, but one which should be tackled holistically, and will ideally need to satisfy three potentially conflicting requirements, the relative importance of which will depend on which stakeholders are considered.

It is only by linking positive soundscapes to higher profile, and what are currently perceived as being more important, issues such as health, business benefits, carbon emissions and air quality that they are likely to become more widely recognised by the key stakeholders in planning processes. Encouragingly this appears to be being recognised by local authorities now, an example being the recent draft noise strategy produced by the City of Westminster [33].

7. Conclusion

The soundscape of a public space can be perceived to be positive. The judgement of "how positive?" is more easily done by comparing soundscapes (for example a new one resulting from an intervention, compared to the existing one) rather than giving an absolute answer.

To fully understand the complexity of what affects "positive" and to understand the relationship between tools that can aid decision makers enhance the soundscapes of public spaces, a structured framework which takes its inspiration from the Kano Model has been created which recognises that:

- Quiet isn't necessarily better.
- It is difficult, if not impossible, to fully describe soundscapes using traditional numerical signal metrics alone.
- Of the factors that can affect positive perception, the majority are unrelated to the sounds themselves.
- The meaning of "positive soundscape" for a public space varies with the level of engagement with the soundscape and is quite different for three types of people:
    - Noise controllers
    - Serious listeners
    - Users of the space
- Most users are more concerned with the activity they are doing in a public space, than listening to the soundscape directly and judging its aesthetic quality or pleasantness. This activity will influence their level of engagement with the soundscape.
- The soundscape is an intermediate step in users' perceptions of a space. Ultimately, the aim should be to enable people to feel as positive as possible about that space.
- Planners could improve the soundscape based upon Kano principles i.e. starting with basic requirements and then on to performance measures and excitement through creativity in sound design.
- A variety of new methods are being developed to generate performance measures.

There is a long way to go before positive soundscapes can be considered part of the normal planning and design process for the built environment. However if a framework can allow stakeholders to better understand the impact of their decisions on the perception of the space through changes to the soundscape, then this is an important first stage. The crucial second stage is the provision and utilisation of improved tools and processes, possibly based on learning within other disciplines or sectors, e.g. automotive product development, to enable them to most easily achieve this. Furthermore the use of tools such as emotional dimensions [21] will help to more strongly link interventions to positive soundscapes and to measures of health and wealth.

8. Recommendations for further work

The framework proposed in this paper is an attempt to rationalise thinking on the concept of positive soundscapes and it takes as its inspiration, approaches which have been proven to work in other domains where listener perception is important – namely automotive sound quality. In order for the framework to be useful to planners and those involved in design decision making for urban environments, it is necessary to illustrate the application of the framework through real-life examples. This requires the creation of an evidence base using experimental data from lab-based and in-situ listening evaluations, and case-studies of how the approaches proposed in our framework have been used.

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