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Non-Participatory Observation Methods and Psychoacoustics for Applied Soundscape Urban Planning: Towards a Preliminary Predictive Agile Framework

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ABSTRACT

More accurate non-participatory parameters and psychoacoustics to assess human perceptual responses to the acoustic environment are critical to inform effective urban sound planning and applied soundscape practice. Non-participatory observation methods are widely used by experts to capture animal behaviour. In 2012, Lavia and Witchel applied these principles and methodologies for the first time to capturing and *assessing human behaviour 'in the wild' to changes to the acoustic environment using added sound and music interventions in a clubbing district. Subsequent work was conducted with Aletta and Kang and Healey, Howes, Steffens and Fiebig to begin characterising the acoustic environment and human responses to align the perceptual and physical findings. Here, the authors report on new work and analysis and propose a preliminary predictive agile applied soundscape framework using non-participatory observation methods and psychoacoustics to be used with environmental assessment practice and evolving urban soundscape planning methods by researchers, practitioners and policy makers.*

Keywords: Soundscape Urban Planning, Psychoacoustics, Body Language, Agile, Applied Research, Perception, Citizens Engagement, Brighton & Hove, University of Sheffield, Noise Abatement Society, Brighton and Sussex Medical School, Queen Mary University of London, Technical University of Berlin, University of Gothenburg, HEAD acoustics

INTRODUCTION

The recent international soundscape standard defines soundscape as the acoustic environment 'as perceived and/or understood by a person/people in context' (International Organization for Standardization [ISO], 2014). For the purposes of urban planning it aligns trans-disciplinary soundscape concepts, in principle, to those of landscape and therefore its frameworks and methodologies (Brown, Kang, & Gjestland, 2011).

In its broadest sense, therefore, a soundscape is neither inherently good or bad in its 'wild' or natural state, but a soundscape's value or affordances are determined based on its ability to support the intended or expected use of a space in a designed (e.g. urban-planned) context (Axelsson, Nilsson, & Berglund, 2010). By this definition, noise pollution is a waste by-product due to ineffectual soundscape management.

Sustainable soundscape planning, therefore, must first identify and define the human perceptual response to an existing, changing or proposed new (i.e. resulting) soundscape in order to provide adequate passive and/or active design specifications for urban sound planners and policy makers (Brown et al., 2011). To do this it is necessary to characterise the acoustic environment relative to the human response in the environment (either actual or proposed) in order to align the perceptual (i.e. human response via non-participatory observation methods and psychoacoustics) and physical (i.e. acoustic) findings.

In this chapter the authors build upon previous work reported by Lavia, Dixon, Witchel, & Goldsmith (2016), and report on new work and analysis to propose *a preliminary predictive agile applied soundscape framework for non-participatory observation methods and psychoacoustics* (Figure 8). The framework is evolved from existing applied soundscape methodology (Figure 1) and proposed to be used in conjunction with traditional environmental acoustic assessment practices and evolving urban soundscape planning methods for researchers, practitioners and policy makers.

BACKGROUND

Numerous studies have linked noise annoyance directly to stress, illness and a variety of adverse health effects (World Health Organization [WHO], 2009). To create liveable cities in the context of rapid urbanisation, the accurate identification, data collection, analysis and interpretation of the causal links between the characteristics and quality of the acoustic environment and people's health and wellbeing is pivotal to informing successful urban soundscape practice. Central to the success of this process is the accurate collection and assessment of people's reactions to the acoustic environment.

Traditionally, in soundscape practice, the human response to sounds in context, as required by the soundscape standard (ISO, 2014), has been collected using recognised self-reporting methods. These include soundwalks, questionnaire surveys, narrative interviews, and jury-based listening tests (ISO, 2016). This means that current methodologies to capture human perceptual responses to the acoustic environment are primarily related to a combination of these participatory methods.

Limitations of Participatory Methods in Applied Soundscape Practice

Because the human response to sound is contextually based, these established (i.e. participatory, self-reporting) methods change attention processes and thus might bias the listener's (natural) perception of the environment. In such cases respondents might be more inclined to assess a sound to which their attention has been directed at the time of the survey and overlook sounds they might otherwise notice or consider important (Schafer, 1994). Also, self-report methods can be biased by the social desirability of the respondents (Paulhus, 1991).

The inherent margins of error in self-reporting methods can be controlled for in certain contexts where the environmental acoustic parameters impacting a person/s experience will remain constant or can be easily controlled by the person/s (e.g. the interior of a car). However, these constants do not hold true in the urban realm where people have little or no control over the acoustic environment that they may encounter.

The Need for Non-Participatory Observation Methods in Applied Soundscape Practice

This means that more accurate parameters to assess the human perceptual response to the acoustic environment in context are critical to inform effective urban sound planning incorporating applied soundscape practice. Non-participatory observation methods are widely used by experts to capture animal behaviour in the wild. Lavia et al. (2012) and Lavia, Witchel, Kang, & Aletta, (2016) and Witchel et al. (2014) applied these principles and methodologies for the first time to capturing and assessing human behaviour based on designed changes to the acoustic environment using added sound and music (i.e. organised sound) interventions in a clubbing district in Brighton and Hove, UK.

Subsequent work was conducted by Aletta, Lepore, Kostara-Konstantinou, Kang, & Astolfi (2016) to begin characterising the acoustic environment at an intervention site to better align the human perceptual responses and physical findings.

This work was extended in the FP7 Sonorus project (Kropp, Forssén, & Mauriz, 2016) to an urban park in Brighton and Hove. This project introduced human perceptual responses into the plans for remedial design interventions for the park which was heavily affected by loud traffic noise (Alves, Estévez-Mauriz, Aletta, Echevarria-Sanchez, & Romero, 2016). While this project did not explicitly use non-participatory observation methods in its analysis of the human perceptual response to the local environmental quality, the work built upon findings from Lavia et al. (2012, 2016a) and Witchel et al. (2014) showing that residents in and visitors to the city responded positively to novel approaches in mixed-use areas in the city's centre.

The Influence Of Music (As A Surrogate for Soundscape Quality) On Human Perception and Behavior

Schafer (1994) referred to the concept of 'orchestrating the acoustic environment'. By this definition, whereas, the urban acoustic environment may or may not be intentionally organized, music *is* a collection of intentionally 'organised sounds'. As numerous (albeit participatory) studies have dealt with the question of how music and soundscape modulate peoples' perceptions of the environment, these researches provide a necessary basis from which to understand, build and expand the study of managing the sounds of the acoustic environment.

For example, in the course of several interview studies, Bull (2001) investigated how people use music to spatially and conceptually reorganize their experience by means of music (Bull, 2000). Recent quantitative research by Yamasaki, Yamada, & Laukka (2015) and Steffens, Steele, & Guastavino (2016) indicates that, when exposed to music, people give more positive judgments of their environment, both in terms of sonic and visual aspects. Several mechanisms underlying the "aestheticising" effect of music have been proposed but have not been systematically investigated. Initial mood for example is hypothesized to mediate the effect of music listening on general judgment processes (Juslin & Laukka, 2004). Music is further assumed to modulate attention processes and to help people focus on or ignore certain properties of their surroundings, e.g. noise (Herbert, 2011).

Observational studies further revealed that (intended) actions could be modulated by music. For example, North, Tarrant, & Hargreaves (2004) demonstrated in a field study that music could reinforce prosocial behavior. The authors observed that gym users who were exposed to uplifting music during a workout were more likely to offer help on a (high-cost) leaflet-distributing task in support of a fictitious sporting charity compared to users who were exposed to annoying music. Observational studies by Areni & Kim (1993), North & Hargreaves (1998), and North, Hargreaves, & McKendrick (1999) further suggest that the choice of music played in shops or cafeterias can affect customers' choices and their willingness to pay more for certain products.

A recent soundscape-oriented study by Aletta et al. (2016) found that the presence of music positively affected the duration people stayed at a public space. In that specific context, classical music was associated with the longest duration of stay and found to be a loitering incentive, while both electronic and classical music excerpts reinforced chatting and eating/drinking activities (Lepore, Kostara-Konstantinou, Aletta, Astolfi, & Kang, 2016). Lastly, Steele, Tarlao, Bild, & Guastavino (2016) installed an interactive sound system (Musikiosk) in a busy public park and explored the effects of this intervention on soundscape perception and behavioral aspects. Amongst others, they showed that the installation improved the perceived pleasantness, eventfulness, and vibrancy of the soundscape for users and non-users alike compared to the pre-installation condition.

Other recent work regarding the participatory human perceptual response to sound has included (Gould van Praag et al., 2017). The researchers: 'conducted an experiment where participants listened to sounds recorded from natural and artificial environments,' during which their brain activity was measured and autonomic nervous system activity was monitored. The research team found that activity in the 'default mode network of the brain (a collection of areas which are active when people are resting) was different depending on the sounds playing in the background.'

Psychoacoustics and Its Relevance For Human Behaviours

Background to Psychoacoustics

The discipline of psychoacoustics intends to arrive at auditory sensation magnitudes analogous to stimulus magnitudes (Fastl & Zwicker, 2007). The auditory sensations take place either on metathetic continua exemplified by loudness or on prothetic continua such as pitch. These categorisations arise from the fact that loudness is an aspect of sound that has what can best be described as degrees of magnitude and quantity, while pitch does not. Pitch varying from high to low has a kind of position, and is a qualitative continuum (Stevens, 1975). The origin of psychoacoustics lies in the tradition of psychophysics assuming that the mapping of physical intensity into mental representations is based on bottom-up processes only. Sensations were considered to be not under control of the mind (Meilgaard, Civille, & Carr, 1991). However, recent studies suggest that top-down processes are involved in the perception of sound as well as asking for a broadening of the concept of psychophysics (Schneider and Parker, 2010). All in all, perception embraces phenomena ranging from simple sensory processes to complex, patterned formations having cognitive and affective components (Helson, 1967).

Psychoacoustics Parameters

Established psychoacoustics parameters cover specific auditory sensations, which can be considered separately. This means that due to specific characteristics of an acoustical stimulus certain auditory sensations are evoked. However, the links between sound properties and auditory sensations are prone to contextual effects (Fiebig, 2015). Even the perception of loudness is not only a relatively low level sensory process, but is a process that fundamentally entails the properties of a cognitive act (Marks, 1992). Thus, psychoacoustics and its scaling are not just about sensory and perceptual processes, but it must deal also with mechanisms of decision and judgment (Marks & Algom, 1998) leading to certain human behaviours. The most prominent psychoacoustic parameter, *loudness*, was introduced several decades ago (cf. Zwicker, 1958). The perception of loudness can be quantified for normal listeners in terms of loudness models (Appell, 2002). Due to the consideration of human signal processing effects like spectral sensitivity, masking effects, critical bands processing and nonlinearities, the psychoacoustic parameter of loudness shows a higher correspondence with the sensation of loudness than any sound level indicator (Genuit & Fiebig, 2012). About one third of the variance of annoyance reactions can be explained by the variance of acoustical features described by sound pressure level indicators (Guski, 1999). However, recent studies show that the psychoacoustic loudness can better explain annoyance data showing its superiority over common sound pressure level indicators (Fiebig, 2015).

The psychoacoustic parameter *sharpness* considers the aspect of timbre, density or brightness and interprets the center of gravity on frequency scale of the spectral envelope; the higher the center of gravity the sharper. Modulated signals elicit two different auditory sensations: At very low modulation frequencies loudness changes can be followed and a sensation of *fluctuation*, whereas higher modulation frequencies evoke a sensation of *roughness*. The psychoacoustic sensation of *tonality* (strength of pitch) describes generally the magnitude of perception of tonal content in broadband noises. Those psychoacoustic parameters have repeatedly shown their relevance for dimensions like quality impression or pleasantness (Lavia, Elliott, Genuit, Fiebig, & Goldsmith, 2013).

Human Perception of Sound Qualities and Cognition

In everyday life, sound experiences including a stream of transient states that vary in intensity from moment to moment need to be interpreted by the hearer in context. This is because humans do not experience their environments by means of meaningless basic auditory sensations without any emotion, feeling or interpretation involved. But sensory input is at least the fundament for perceiving, experiencing and constructing the environment. Humans construct their perceptions from sensations and from long-term memory of past experiences with similar sensations (Fisher, Bell, & Baum, 1984) indicating the relevance of psychoacoustics. If humans reflect on experienced episodes, the derived retrospective summary evaluations are important input into decisions to repeat or avoid past experiences bearing direct hedonic consequences (Ariely & Carmon, 2000). This might be the primary function of senses guiding ongoing behaviour and exerting considerable influences on the memory associated with the original moment-to-moment sensations (Algom, 2001). Those conscious or unconscious summarized evaluations representing streams of transient states varying over time are the basis for future decisions such as avoiding or revisiting certain places.

However, the perceived stream of moment-to-moment sensations depends on attention processes and cognitive processing. Since hearing is the primary early-warning system remaining sensitive to new objects, this sense strongly guides particularly attention (Scharf, 1998). Attention guides to a certain extent how humans perceive and evaluate their environments. Gained information, which due to mechanisms of attention gets access to working memory, is evaluated and analysed, decisions about that information are made, and plans for action can be elaborated (Knudsen, 2007). Any attention towards a stimulus leads to a cognitive benefit, whereas at the same time other stimuli lose importance (cognitive deficit). Moreover, it was found that in the presence of numerous sound sources, acoustical sceneries are processed as a whole rather than as independent sound events (Guastavino, Katz, Polack, Levitin, & Dubois, 2005).

Attention processes are influenced by source recognition; as soon as a sound source is recognised, attention is sharpened separating the source from the background and influencing basic auditory sensations like loudness perception (Hellbrück, Fastl, & Keller, 2004). Probably, the need for a selective auditory attention ability (i.e. in order to focus on a certain sound source while ignoring temporarily other sound sources) has its origin in the evolutionary requirement to immediately recognise potential danger (Steffens, 2013). This means that both top-down processes (voluntary) and bottom-up mechanisms (saliency-based) are relevant parts of human (sound) perception. Due to its relative signal strength and behavioural importance certain information gains access to working memory by a competitive process including top-down and bottom-up processing.

The information with the greatest signal strength enters the working memory and competes with existing information for control of working memory. This concept includes that for improving information quality, sensitivity can be modulated by top-down mechanism improving signal-to-noise in all domains of information processing. At the same time stimulus-driven access to working memory could occur (bottom-up attention), when salient stimuli occur infrequently in space or time. These mechanisms selectively gate incoming auditory information enhancing responses to stimuli that are conspicuous (de Coensel & Botteldooren, 2010).

It is assumed that the relative signal strength or conspicuousness of acoustic signals is related to auditory sensation magnitudes. It seems likely that psychoacoustic parameters describing specific characteristics of sounds are related to the relative signal strength attracting attention and gaining access to the working memory. Further, even if attention is not directly focused on sound, an inattentional processing of sound still occurs allowing people to remember aspects of sound after perception (Skoda, Steffens, & Becker-Schweitzer, 2013).

To describe memorised conspicuous sound properties, novel parameters grasping mainly specific patterns in the time and frequency domain are needed, like the Relative Approach quantifying spectral patterns and rapid time-varying structures (Sottek & Genuit, 2005). Unfortunately, due to the proximity of psychoacoustics to traditional psychophysics with its methods and approaches, psychoacoustics is rarely applied in the context of non-participatory observation methods. At least, non-deceptive obfuscation experiments, which prevent the direct attraction of attention to sound, have been proven to be beneficial and thus can achieve a higher level of ecological validity (Steffens, 2013).

Psychoacoustics Parameters as Independent Variables in Applied Soundscape Practice

However, recent psychoacoustic measures as independent variables are rarely considered in non-participatory observation methods even if sound properties evoking a certain arousal are likely to attract attention and thus can guide human behaviour. The Brighton Tunnel Soundscape experiment (Lavia, Witchel, Kang, & Aletta, 2016b; Witchel et al., 2014) underscored the impact of sound and its properties on human behaviour and conducted preliminary explorations regarding the role of psychoacoustics. Subsequent work conducted by Kang, Hao, Yang, & Lavia (2015) have considered psychoacoustic measures as independent variables and found these positively correlated with known sources of noise annoyance in relation to traffic and industrial noise.

Howes, Healey, Lavia, & Fiebig (2014) investigated the human response and social interaction in relation to sound sources from machines in a particular social context as illustrated in the Case Study below. They found that intrusive (e.g. annoying) sounds were directly correlated with the observed perceptual responses of the participants. In this study, psychoacoustic parameters were used to assess the characteristics of the sound sources and these showed a direct correlation with known acoustic characteristics causing annoyance or alarm in other studies (Lavia et al. 2013).

Other recent work regarding the participatory observed human perceptual response to sound has included (Gould van Praag et al., 2017). The researchers 'conducted an experiment where participants listened to sounds recorded from natural and artificial environments,' during which their brain activity was measured and autonomic nervous system activity was monitored. The research team found that activity in the 'default mode network of the brain (a collection of areas which are active when people are resting) was different depending on the sounds playing in the background.'

Evolving the Current State of the Art

These research projects provide ever more compelling links indicating how to objectively observe and evidence the human perceptual response to sound in context in controlled or pre-defined conditions. However, there is still the need to synthesise the methods from existing applied soundscape studies in order to evolve the current state of the art. This is important to incorporate a preliminary predictive agile applied soundscape framework for non-participatory observation methods and psychoacoustics with existing practice. Figure 1 illustrates a simplified applied soundscape framework representing a general view of current practice. It is envisioned that an evolved or combined model can be used in the context of urban sound planning and developed in order to provide more robust predictive outcomes for specific use cases.

Figure 1. A simplified soundscape framework representing a general view of current practice [INSERT FIGURE 1]

Practitioners Context

The role of planners and designers is to decide about the use of an environment and physically transform that environment for such use to happen. In doing this, they have traditionally referred to a merely 'visual' framework to explore, gather information, and communicate their designs about how the environment should be. In spite of being a key component of our everyday experience of urban environments, sound has often been disregarded (Easteal, Bannister, Kang, Aletta, Lavia, & Witchel, 2014). Soundscape researchers are pushing urban planners and design consultants to overcome a creative process unilaterally driven by 'vision' and to question how the acoustic environments would affect the perceived urban quality and how sounds could be used in practice. Southworth in the late 1960's started the debate about the 'sonic identity' of cities, and how this would be developed together with their visual identity (Southworth, 1969).

There has been far more attention for sound design from a commercial or business perspective, rather than from a planning and urban design one. Over the last decades, marketing professionals have investigated the influence of environmental sounds and music on peoples' behaviour in terms of activity or performance; for instance, time spent in a retail area, productivity, money spent in a restaurant. It is unfortunate that although several studies explored how to exploit the soundscape concept to direct consumers' behaviour, urban design practitioners have shown little attention to soundscape's potential for promoting healthy urban environments (Alves, Altreuther, & Scheuren, 2014; Lepore, et al., 2016).

Lavia and Witchel and colleagues, with the support of local authorities and NGOs, have shown that it was possible to improve crowd behaviour and to decrease anti-social behaviours overall by manipulating the outdoor acoustic environment with a "tailored" soundscape; i.e., by having a sound artist adding sounds and playing live music onto the main street of the city's busiest clubbing and entertainment district in Brighton and Hove (UK), during a one-night intervention (Lavia et al., 2012; Witchel, Lavia, Westling, Healy, Needham, & Chockalingam, 2013). Likewise, using music and fake human sounds (e.g., voices, laughter), Sayin and colleagues managed to increase the perceived safety of people in public places, such as car parks, public transport stations and isolated green areas and parks, which are often associated with people's reluctance and avoidance (Sayin, Krishna, Ardelet, Briand Decré, & Goudey, 2015).

For designers to have a good baseline to start their design proposals, it is necessary to gather data that are as representative as possible of the actual perception of the acoustic environment in a place. Many firms and practices tend to opt for *ante operam* social surveys, but such on-site campaigns are often biased by what Brown and colleagues call the "experimenter effect", raising the issue that "[…] *measurement of people's preference in these situations using questionnaire methods requires first drawing their attention to something upon which they may never have consciously reflected.*" (Brown, et al., 2011). This is why non-participatory observation methods might be more valuable for soundscape assessment and design, even though they have not been paid much attention so far in soundscape research (Aletta, Kang, & Axelsson, 2016; Aletta, et al., 2016).

Practitioners are increasingly likely to receive a mandate from policy makers to modify the acoustic environment of a place. To do this they will need to operate at two different practice levels; namely: (1) planners – mostly making decisions about the type of use for a space (e.g., local authorities or urban planners); (2) designers – implementing the physical transformation of the space to facilitate the desired use (e.g., acoustic consultants, landscape architects). From a practitioner's perspective, there should then be a necessity to understand the relationships between "good" urban environments and social cohesion through the identification of indicators which can provide soundscape quality for the built environment (Lavia, et al., 2012). There is a need for a new generation of professionals (both at a planning and design level) for the urban realm who would cover a broad spectrum of competences, ranging from environmental acoustics principles, to architectural and technological knowledge, and to behavioural analysis skills (Alves, et al., 2015). This is necessary to facilitate the implementation of a soundscape dimension at an early stage of the planning (and design) process (Payne, Davies, & Adams, 2009). The aim should be to shift the professionals' focus from a mere noise control engineering perspective to an urban sound planning one.

HUMAN PERCEPTUAL RESPONSE TO SOUND

In Participatory Methods

Participatory methods, e.g. surveys or interviews, are an essential element of psychological and sociological research. However, they bring about certain limitations which constitute validity threats, both with regard to the internal and the external validity of the research outcome (Feldman & Lynch, 1988). The so-called reactivity bias refers to the effect that people might alter their behavior or performance when they know that they are being observed (Campbell & Stanley, 1966). For example, research participants might tend to behave in a socially desirable manner ("social desirability bias"; Edwards, 1957) or in a way that is presumably demanded by the researcher and/or the situation (Orne, 1962). Furthermore, acquiescence describes the phenomenon that people tend to agree with all the questions they are asked, especially when they are in doubt (Watson, 1992). Current research suggests that this behavioral tendency can be considered a person-related factor – a specific cognitive style which is independent from the subject under investigation (Knowles & Nathan, 1997).

In soundscape research, the reactivity bias can be extended to effects which occur in the course of alterations in the participants' focus of attention. In every study in which people are required to evaluate sounds while listening to them, the experimental task makes the test participant focus on the auditory stimuli being evaluated, regardless of the test environment or the methodology. This test-dependent attention focusing leads to incongruities compared to everyday listening where auditory attention processes are guided by intended or executed actions (Fagioli, Hommel, & Schubotz, 2007) and/or the saliency of environmental sounds (Kayser, Petkov, Lippert, & Logothetis, 2005). The alteration of attention processes might have severe effects on soundscape evaluations since it draws peoples' attention to elements of a soundscape which might have not been perceived in an everyday life-like situation. Research on auditory attention processes in real life or the effects of attention focusing on soundscape evaluations is still scarce. Findings from Steffens (2013) and Skoda et al. (2013), however, suggest that attention focusing in soundscape studies has the effect of a magnifying glass, which means it might lead to overestimations of loudness and unpleasantness as well as of the perceived differences between two sounds.

Conducting participatory soundscape studies can also change people in the long-term, e.g. sensitize them for sounds in general and increase awareness for the sonic environments. One does not necessarily have to consider this a methodological artefact, it can also be a key aim of certain methods used in soundscape research, e.g. certain soundwalk techniques which are designed to help people "cleaning" their ears and to sensitize them for their sonic environment (Schafer, 1967).

Summing up, participatory methods mostly alter peoples' experiences which might lead to biased research outcomes. Here, non-participatory methods are an ideal tool to complement the methodological "toolkit". Such observational methods can be particularly useful in the context of soundscape and music research, as they do not interfere with the peoples' perceptual and behavioral processes.

In Non-Participatory Measurement of Soundscape Interventions Using Nonverbal Behaviour

Sound influences many behaviours via changes in cognitive state, and the behaviours can feedback via sound-producing behaviours (Figure 2). The cognitive states elicited by soundscape and music (Zentner, Grandjean, & Scherer, 2008) are more broad than Ekman's discrete emotions (Biehl et al., 1997). The mental states elicited may be approximated by the PAD model of emotions, which include valence (positive to negative), arousal, and dominance (empowerment) to submission (Mehrabian, 1996). Two additional axes are relevant to soundscape: familiarity-novelty (Axelsson et al., 2010) and the social responses of belonging-alienation (Koelsch, 2010). The axes of cognitive states and their related behaviour sets are shown in Figure 3.

Figure 2. Mechanistic relationship between soundscape, cognitive state and measurable behaviours (Adapted from Zentner et al., 2008 and Biehl et al., 1997)
[INSERT Figure 2]

Figure 3. Classification of soundscape effects. Axes of cognitive states are shown horizontally and vertically. Behaviours elicited by those cognitive states are shown on the diagonals (in dashed rectangles). The cognitive variations caused by valence are implicitly incorporated in the opposite ends of each axis (Adapted from Axelsson et al., 2010 and Koelsch, 2010).
[INSERT Figure 3]

Arousal has functions as both a mental state and as a behavioural state (Thayer, 1978). Music is known to affect both the mood and activity of people who listen to it. The Brighton Tunnel Soundscape experiment involved testing the effects of soundscape interventions in a public pedestrian underpass on large numbers of pedestrians who were not alerted to the experiment, with appropriate ethical safeguards and approvals in place (Witchel et al., 2014). Data was gathered via closed circuit television cameras (which are ubiquitous in public spaces in the UK), and was analysed either using trained scorers or with computer vision. In one aspect of the Brighton Tunnel Soundscape experiment, two different recordings of the same musical excerpts were presented to pedestrians, where one version was slightly faster (106 beats per minute vs. 116 beats per minute). Preliminary results demonstrated that faster music was associated with faster walking, and that this occurred after only a 30-second interval of exposure [Figure 4, (Lopez-Mendez et al., 2014)]. While this finding was demonstrated with manual frame-by-frame analysis, it was also shown that the movements (and heel strike of the gait, in particular) could be recognised with high accuracy using computer vision.

Figure 4. Walking rates through the tunnel in response to two different tempos of an otherwise identical musical excerpt ("Cirrus" by Bonobo) (Lopez-Mendez et al., 2014)
[INSERT Figure 4]

The other aspect of arousal is tension vs. calm, which relates to conflicts between what is needed/wanted vs. what is present. Music and soundscape are particularly related to this continuum because hearing is immersive. In the Brighton Tunnel Soundscape experiment, one measurement made, given that the experiment ran in the night-time, was what effect the music had on loiterers. The tunnel is a thin, artificially lit underpass that lacks any seating, yet occasionally groups and sometimes individuals would sit or lie down on the concrete floor for extended periods (2 minutes to hours). The authors defined loiterers as people who were on camera as remaining in the tunnel for over one minute (when it takes approximately 30 seconds to traverse the tunnel by walking). The authors also tested whether some music was more often associated with loitering beginning (i.e. a welcoming soundscape) or with loitering ending (an aversive soundscape), and in preliminary results for two Saturday nights, it was found that, of four soundscape (3 musical excerpts vs. silence), entries during silence were increased above values for the jazz and classical pieces, while exits during classical music were enhanced compared to jazz and contemporary dance.

Social territorial behaviour can be summarised as a combination of space occupation and marking (often with sound as well as possessions) in order to reinforce feelings of belonging and empowerment (Witchel, 2011). The loitering survey of the Tunnel Project highlights that territoriality can be influenced by music both in terms of approach and withdrawal. Changes in social territory are a common effect of controlling the soundscape, especially with music appropriate to a particular social group. One observation of the Brighton Tunnel Soundscape experiment is that when the recorded music was on, buskers did not engage with the tunnel, despite the fact that it was normally popular with buskers because of its reverberant properties.

Engagement differs from, and can incorporate, attention; it is less momentary, more consequential and more diverse than attention (Witchel, Santos, Ackah, Westling, & Chockalingam, 2016). Attention focuses on gaze direction as both an indicator and a result, but the immersive quality of sound – and especially music – means that attention to sound is independent of gaze direction, so the English language makes a distinction between hearing and listening. Engagement can occur directly with the environment, or with the actors in it, while disengagement can be directed at the environment as a whole. This often manifests as looking at a device, looking down to the ground, or looking at someone's back, such as when queuing. In the original White Night project in the clubbing district of Brighton from 7 PM to midnight (Lavia et al., 2012), observational scoring of whether individuals queuing were facing face-to-tail (closed queuing) or more open queuing showed that a pervasive slow-music soundscape led to subtle increases in open queuing (Figure 5). This engagement was not simply an engagement with the soundscape intervention, but a more general engagement with the environment as a whole.

Figure 5. Fraction of people queuing on the pavement in an open vs. closed form on two different pleasant Saturday evenings on Brighton's busiest clubbing street. During the interventional evening, a 3-Dimensional pervasive (but not overbearing) soundscape was curated, based on slow music. During the control evening, traffic and shouting were the dominant sounds on the street. (P = 0.0065, Ntotal = 244). (Lavia et al., 2012)
[INSERT Figure 5]

As a test of whether a soundscape intervention can make people more pro-social, music was presented to pedestrians while they crossed the tunnel to test if different musical excerpts could alter the charitable donation rate for collectors at the far end of the tunnel. The music was non-vocal and matched for loudness and tempo but had different genres (i.e. classical, jazz, and contemporary dance, vs. silence), and the collectors waiting for donations were instructed to smile at everyone and to show their buckets (there were signs on the buckets for a well-known British charity), but otherwise to avoid possible variations in accosting. It was found that the classical music excerpt (Handel's "Alcina" overture) was associated with a donation rate that was twice as large as silence (13.3% vs. 5.3%); both the Jazz (Benny Goodman's "Sing Sing Sing") and the contemporary music ("Cirrus" by Bonobo) elicited donation rates (8.8% and 7.8% respectively) that were halfway between silence and Handel.

Engagement with people, or with other independent social-substitute agents such as animals or audiovisual recordings, can include gaze direction, proxemics [e.g. approach (Harrigan, 2005)], and touching. One of the most useful behaviours for measuring non-participatory engagement is entrainment, which is the synchronisation in time of movements of two actors/agents. Commonplace examples of entrainment include handshakes (where the hands of two people move in synchrony), playing fetch (where the human picks up the ball/stick and throws it whenever the dog brings it back), and dancing (where dancers movements are coordinated to the pulse of the music).

The experiment above in the Brighton Tunnel Soundscape experiment, where faster music made people walk faster, is a simple example of entrainment, and the ultimate goal of that study is to test for explicit entrainment of walkers' phase and cadence to the music. Another aspect of entrainment is the elicitation of appropriate behaviour; although the tunnel experiment occurred in public space, an occasional (but repeating) feature of the filmed data was that late night groups (possibly inebriated) would respond to Tchaikovsky's "Waltz of the Flowers" by ballet dancing.

In conclusion, soundscape interventions alter human behaviour (sometimes subconsciously). These changes in behaviours can manifest as rates of behaviour, directions of behaviour, or as entirely new behaviours, which can be measured in appropriately ethically approved experiments by public CCTV cameras. Researchers are increasingly able to computerise non-participatory studies to quantify these changes.

Case Study On The Social and Emotional Impact of Intrusive Sound Using Participatory Measurement Of Nonverbal Behaviour

In this study the authors (Howes et al., 2014)[1] investigated the effects of intrusive sounds (i.e. judged as unwanted and therefore noise) on people interacting in a kitchen setting. The results show three different effects of context on their responses. First, congruent sound sources i.e. those which are expected in context (e.g. a kettle) cause less disruption than incongruent sound sources (e.g. a garden strimmer). Second, sounds that can be attributed a clear apparent cause are less disruptive than those that are apparently random. Third, there is an effect of social context in that if the cause of the sound is a person, the form of people's responses depends strongly on the way in which the disruptive sound is introduced by that person.

Background

This project investigated the effects of intrusive sound on people in naturalistic domestic settings. In soundscape studies, noise is defined as 'unwanted sound' (ISO, 2014) and/or the wrong sounds in the wrong context. This study assumed that the sounds presented to the participants had the potential to cause annoyance because of their context and/or their sound quality characteristics (e.g. which can be determined through psychoacoustic measurements). The authors chose each sound in this study based on recommendations from the Noise Abatement Society (an NGO based in the UK) as a result of complaints received to its Helpline from citizens regarding the respective sound sources. The use of the term 'noise' in this study is used with this assumption as the basis.

Controlled laboratory studies have established that noise, especially loud and unpredictable noises, can have detrimental and sometimes persisting effects on cognitive performance (see e.g. Cohen, 1980; Laszlo, McRobie, Stansfeld, & Hansella, 2012; Szalma & Hancock, 2011, for reviews). These studies often use controlled bursts of artificially generated sound such as white noise and typically assess their effects through measures of physiological responses or by measuring interference with people's performance on concurrent tasks such as memorising, proof-reading and problem solving. This project aimed to connect this research more directly with the ecology of everyday life and to understand the social and emotional effects of intrusive noise in the contexts and activities in which they are normally encountered.

The key factors thought to influence how disruptive a sound source is, are a) the *predictability* of the source i.e., the extent to which the onset of the sound is expectable and b) the meaning of the sound in context, i.e. whether or not the sound has a recognisable meaning and makes sense in the context of the ongoing activity – its *contextual incongruence*. The authors manipulated the predictability of each sound by switching each appliance on either automatically or as part of a visible course of action by the experimenter. The authors manipulated the contextual incongruence of each sound through the use of a food tasting task in which the different appliances vary in their degree of contextual appropriateness.

The authors predicted that interruptions would have a negative social and emotional impact and that this would reduce the quality of participants' interactions. The authors also predicted that unpredictable sounds would have a more severe impact than predictable sounds, and out-of-context sounds (those with a high contextual incongruence) would have a more severe impact than those in-context.

What Was Done

Staff at the Good Housekeeping Institute were invited to participate in a taste-testing. They came in pairs and were presented with eight different types of houmous to taste and rate together. Each person was videotaped for the duration of the experiment, and given a £10 John Lewis (i.e. a UK store) voucher to thank them for their time after the experiment. However they did not know that the taste-testing task was only a 'cover story' – the true purpose of the experiment was to investigate how the participants responded to intrusive sounds. During the tastings, for half of the pairs, the experimenter started several noise making appliances (a kettle, a hairdryer, a vacuum cleaner, a juicer, a strimmer and a tonal 'beep beep' reversing alarm) at random times – either *predictably* (i.e. making it obvious that they were doing so, by walking up to them and pressing the on switch), or *unpredictably* – by remote control. The pairs who did not hear any appliances during the tasting, were asked to listen to them afterwards (hence they were highly predictable). They were also asked to rate each sound for how annoying and how unexpected it was in the context of the test kitchen, as a measure of *contextual incongruence*.

What Was Found

Although the presence of noises did not have any effects on people's ratings of the houmous, they did have an effect on how people interacted with each other. To look at this the authors analysed people's facial expressions for how surprised they looked and how happy they looked in the first five seconds that they heard the sounds, using automatic facial recognition software [(SHORE™) Fraunhofer Institute 2017)]. The six noisy appliances were categorised into two groups based on how they had been rated. The kettle, vacuum cleaner and hairdryer were rated as having a low-level of annoyance, and low-level of unexpectedness, and were thus judged as having *low contextual incongruence*. However, people found the noises made by the juicer, the 'beep beep' reversing alarm and the garden strimmer to be highly annoying and unexpected, i.e. they had *high contextual incongruence*.

Surprise

As might be expected, people looked more surprised when they heard a noise from an appliance that seemed to start itself rather than a noise that was predictable (Table 1). People also found the highly contextually incongruent noises somewhat more surprising that the congruent noises. This can be seen in Figure 6, where the flat dashed line shows the baseline level of expressed surprise (0.60) when there was no noise. The reported results were obtained using GLMM models and all statistical analyses can be seen at Howes et al. (2014).

Table 1. Amount of surprise during first five seconds of the noise by predictability and contextual incongruence (Howes et al., 2014)
[INSERT TABLE 1]

Figure 6: Amount of surprise by predictability and contextual incongruence (Howes et al., 2014)
[INSERT FIGURE 6]

Smiling

More intriguingly, people smiled more if the source of the noise was predictable, actively suppressing their smiling when the noise apparently started at random (Table 2). This is illustrated in Figure 7 where the dashed line shows the baseline level of smiling when there is no noise at 20.3). When the noise was highly contextually incongruent, people smiled even more if the experimenter was both the predictable source of the noise, and interacted with them (by telling them they would hear a noise that they had to rate), than if there was no interaction with the experimenter. This shows that the predictability and source of the noise is a crucial factor – not just the noise itself.

Table 2. Amount of smiling during first five seconds of the noise by predictability and contextual incongruence (Howes et al., 2014).
[INSERT TABLE 1]

Figure 7: Amount of smiling by predictability and contextual incongruence
(Howes et al., 2014)
[INSERT FIGURE 7]

Conclusions:

The results show three different effects of context on people's responses to noise in a domestic setting. First, congruent noise sources i.e. those which are expected in context (kettle, hairdryer, vacuum cleaner) cause less disruption than incongruent noise sources (a garden strimmer, reversing alarm, juicer). Second, noises that can be attributed a clear apparent cause are less disruptive than those that are apparently random. This effect is much larger than the effect of congruence. Third, there is a marked effect of social context in that if the cause of the noise is a person, the form of people's responses depends strongly on the way in which the disruptive noise is introduced by that person. This means that situation and context are critical in considerations of noise standards; the physical signal of the noise alone is insufficient.

In addition as part of this study, psychoacoustic data was also collected and used to assess the characteristics of the sound sources. These results showed a direct correlation with known psychoacoustic characteristics causing annoyance or alarm, as mentioned previously, in other studies with similar machines and appliances (Lavia et al., 2013).

This case study helps to further illustrate the importance of combined observational assessment approaches with psychoacoustics for soundscape management, as illustrated in Figure 8. The types of sounds heard, their qualities, how they propagate in the environment and their appropriateness (aligned with the expectations of the hearer) directly affects how the sounds will be perceived and how the hearer will view/react to their environment and others.

Figure 8. A preliminary predictive agile applied soundscape framework for non-participatory observation methods and psychoacoustics. The model can be used in the context of urban sound planning methodology and developed in order to support the development of more robust predictive outcomes for specific use cases.

[INSERT FIGURE 8]

FUTURE RESEARCH DIRECTIONS

Non-participatory methods, as opposite to participatory methods, in soundscape research can help overcome a number of biases which could highly affect the data about the perception of the acoustic environments. On the other hand, there is a need to develop robust protocols for these kind of behavioural observations in order to make non-participatory soundscape studies comparable for particular use cases and, potentially, worldwide.

Further testing and querying of the behavioural and perceptual data captured from the series of experiments and future work is needed to align it with properties of the acoustic environment, for example musical and psychoacoustical features. This is important to support further investigations regarding the relationships between the physical characteristics of the acoustic environment and the human perceptual response in context inline with *a preliminary predictive agile applied soundscape framework for non-participatory observation methods and psychoacoustics* (Figure 8).

It is also important to triangulate non-participatory behavourial results with the psychoacoustic and acoustics data using automated processes to develop more robust tools and methods to assess which characteristics of the acoustic environment can have consistent effects on behaviour in particular use cases and contexts.

The application of non-participatory methods in the context of soundscape research is also needed in order to identify and eliminate biases associated with participatory methods and at the same time to learn more about the potential drawbacks of non-participatory methods. In this context it is imperative to work further on the operationalization of behavioral phenomena allowing for measuring reliably and testing hypotheses scientifically. For example, the general satisfaction with an acoustic environment might not be directly observable, but with the adequate operationalization of this phenomenon using theories, concepts and empirical evidence it will be measurable.

CONCLUSION

The authors assert that the use of more accurate non-participatory parameters and psychoacoustics as independent variables to assess the human perceptual response to the acoustic environment are critical to inform effective urban sound planning and applied soundscape practice. To do this it is necessary to develop better assessment tools, based on the current state of the art, and methodologies for specific contexts and use cases. The authors have done this by evolving existing applied soundscape methodology (Figure 1) and building upon this to propose *a preliminary predictive agile applied soundscape framework for non-participatory observation methods and psychoacoustics* (Figure 8).

It is envisioned that this evolved model can be used in conjunction with traditional environmental acoustic assessment practices and emerging urban soundscape planning methods for researchers, practitioners and policy makers. The framework is designed to be applied to specific urban use cases. It provides a consistent framework which can be adapted to multiple urban cases to support the development of more robust predictive outcomes.

Regarding the participatory human perceptual response the authors have shown that non-participatory observational methods are important, useful and even (in some cases) superior to participatory methods in the context of soundscape practice. This is because they do not interfere with the peoples' perceptual and behavioural processes. However, other aspects like the ethics of such approaches must be carefully considered.

The human perceptual response directly affects how sounds will be perceived and how the hearer will view/react to their environment and others. In this paper the authors connected this understanding more directly with the ecology of everyday life, in applied contexts, to understand the social and emotional effects of intrusive noise or positive sound and activities in which they are normally encountered.

In conclusion, as stated, soundscape interventions alter human behaviour (sometimes subconsciously). These changes in behaviours can manifest as rates of behaviour, directions of behaviour, or as entirely new behaviours, which can be measured in appropriately ethically approved experiments (e.g. by public CCTV cameras). This means that researchers are increasingly able to computerise non-participatory observation studies to quantify these changes. These findings when connected with data, analysis and understanding from the field of pscyhoacoustics provides the necessary ability to support predictive agile applied soundscape frameworks, like the one presented in this paper (Figure 8).

The effective synthesis of objective and subjective data and analysis will provide better insights and assessment capabilities for practitioners to underpin urban sound planning processes. These tools, processes and methodologies will help enable better and more accurate decisions to be taken at the design and specification stages in urban planning and development.

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KEY TERMS AND DEFINITIONS

Artefacts: an effect or phenomenon found or observed in the course of a scientific investigation or experiment that occurs as a result of the preparative or investigative procedure but which may not be present otherwise

Non-Participatory Observation: a scientific investigation or experiment in which the participants are or are not aware of the observations taking place and in which they are not taking an active part in the study

Soundscape: Soundscape means an acoustic environment as perceived or experienced and/or understood by a person or people, in context (ISO, 2014). The concept of soundscape considers different perceptual dimensions underlying the perception and health, wellbeing and/or ecological value of acoustic environments in contrast to traditional environmental noise assessment practice (ISO, 2016), where sound tends to be understood and interpreted from the perspective of its likelihood of causing annoyance.

Psychoacoustics: Psychoacoustics as a branch of psychophysics describes quantitatively the relationship between an acoustical stimulus and the evoked auditory sensation. Sometimes higher cognitive processing stages of sound are also considered to belong to the discipline of psychoacoustics.

Self-Report Method: a scientific investigation or experiment in which the participants cognisantly, consciously participate and select/provide their responses with or without a researcher present.

Urban Sound Planning: an emerging multi-discipline between acoustics, soundscape and urban planning with the aim of designing holistic acoustically favourable environments suitable to the context from the perspective of the 'users of the space' and their expectations.

ENDNOTES

[1] This study was kindly supported by Queen Mary University London, the Noise Abatement Society, HEAD acoustics, Quiet Mark™, and the Good Housekeeping Institute. The original study idea was developed by Lisa Lavia and adapted with Poppy Szkiler, the experimental design was developed and conducted by Christine Howes and Patrick G.T. Healey, the sound quality and psychoacoustics analysis was conducted by André Fiebig.

Figure 1. A simplified soundscape framework representing a general view of current practice.

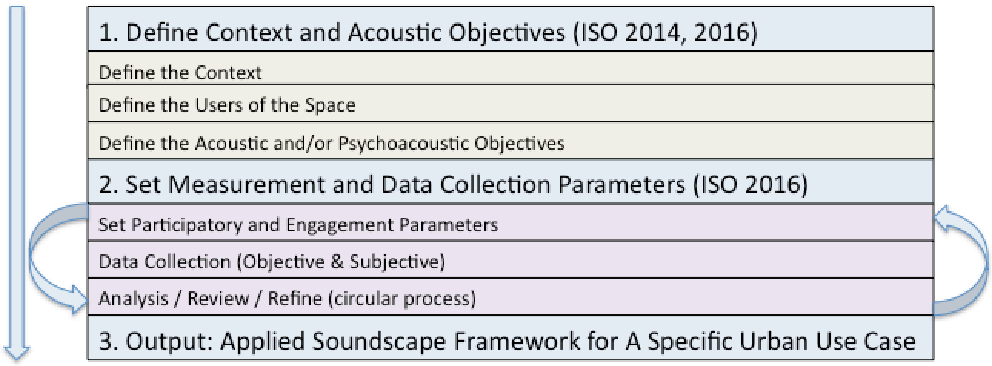

Figure 2. Mechanistic relationship between soundscape, cognitive state and measurable behaviours. (adapted from Zentner et al., 2008 and Biehl et al., 1997)

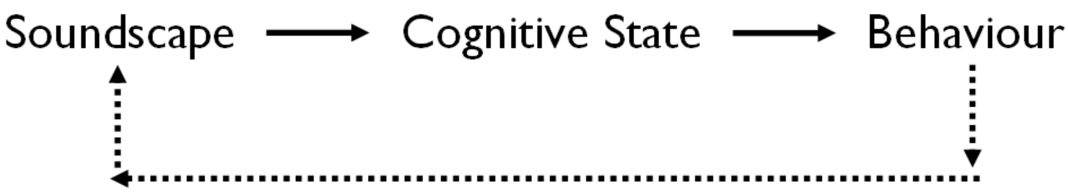

Figure 3. Classification of soundscape effects. Axes of cognitive states are shown horizontally and vertically. Behaviours elicited by those cognitive states are shown on the diagonals (in dashed rectangles). The cognitive variations caused by valence are implicitly incorporated in the opposite ends of each axis.(adapted from Axelsson et al., 2010 and Koelsch, 2010).

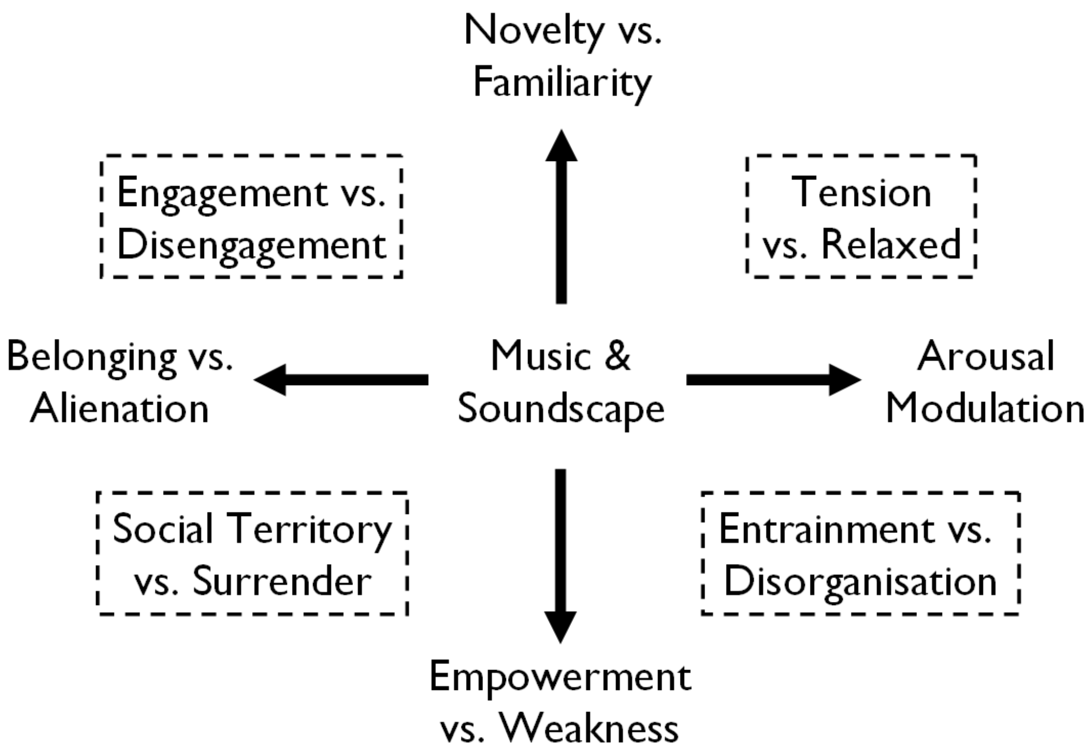

Figure 4. Walking rates through the tunnel in response to two different tempos of an otherwise identical musical excerpt ("Cirrus" by Bonobo). (Lopez-Mendez et al., 2014)

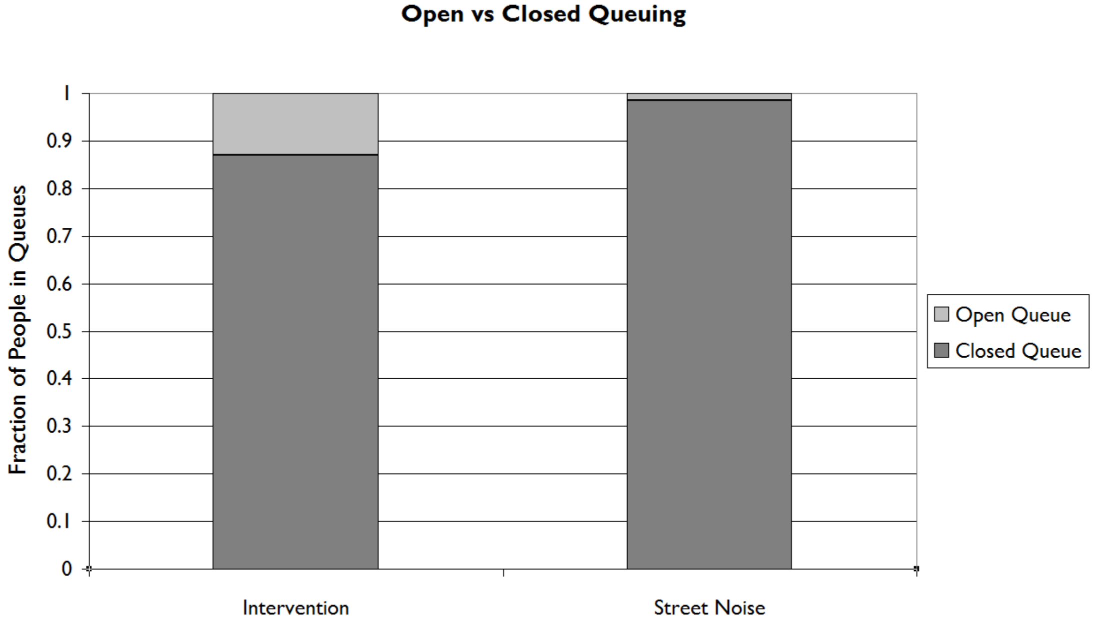

Figure 5. Fraction of people queuing on the pavement in an open vs. closed form on two different pleasant Saturday evenings on Brighton's busiest clubbing street. During the interventional evening, a 3-Dimensional pervasive (but not overbearing) soundscape was curated, based on slow music. During the control evening, traffic and shouting were the dominant sounds on the street. (P = 0.0065, Ntotal = 244). (Lavia et al., 2012)

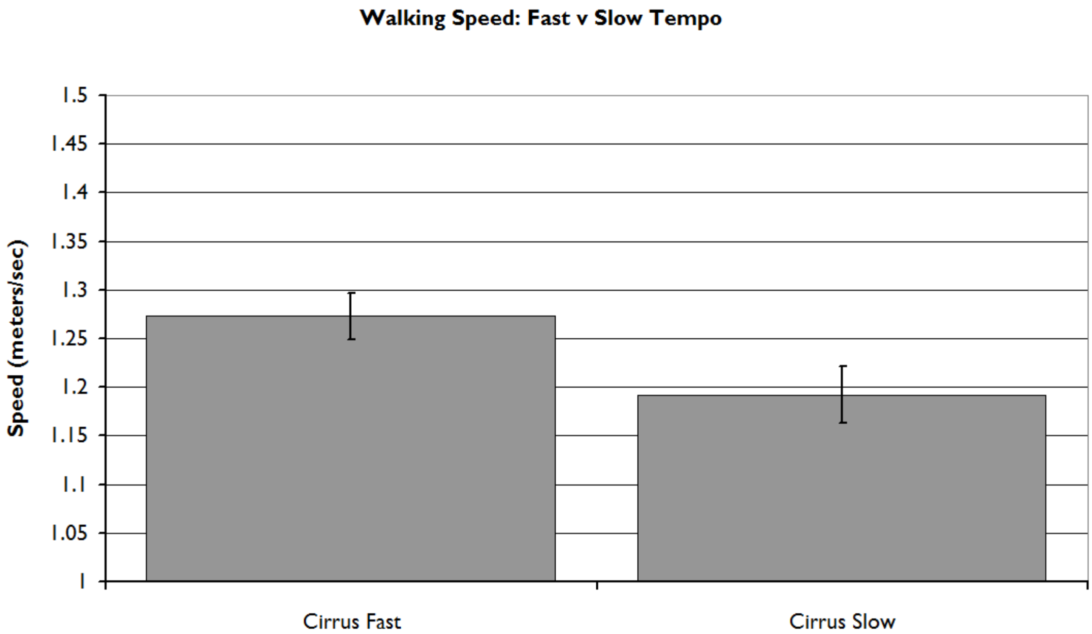

Table 1. Amount of surprise during first five seconds of the noise by predictability and contextual incongruence (Howes et al., 2014)

	Contextual incongruence					
	High		Low		Total	
Predictability	Mean	Count	Mean	Count	Mean	Count
Predictable noise (control group during rating)	.88	120	.33	120	.59	240
Predictable noise (started by experimenter during tasting)	1.10	60	.36	60	.71	120
Unpredictable noise (started by remote control during tasting)	7.69	55	6.15	55	6.92	110
Total	2.90	235	1.86	235	2.36	470

Figure 6: Amount of surprise by predictability and contextual incongruence (Howes et al., 2014)

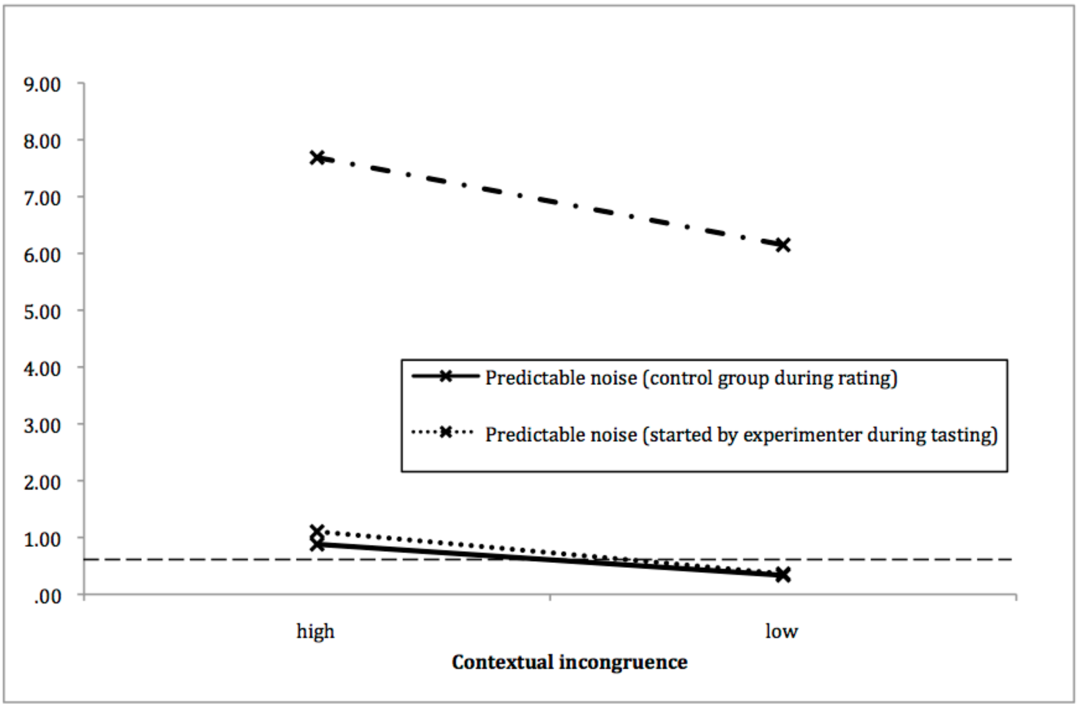

Table 2. Amount of smiling during first five seconds of the noise by predictability and contextual incongruence (Howes et al., 2014).

	Contextual incongruence					
	high		low		Total	
Predictability	Mean	Count	Mean	Count	Mean	Count
Predictable noise (control group during rating)	39.17	120	33.03	120	35.88	240
Predictable noise (started by experimenter during tasting)	25.14	60	34.94	60	30.30	120
Unpredictable noise (started by remote control during tasting)	15.96	55	17.58	55	16.77	110
Total	28.59	235	29.52	235	29.08	470

Figure 7: Amount of smiling by predictability and contextual incongruence (Howes et al., 2014)

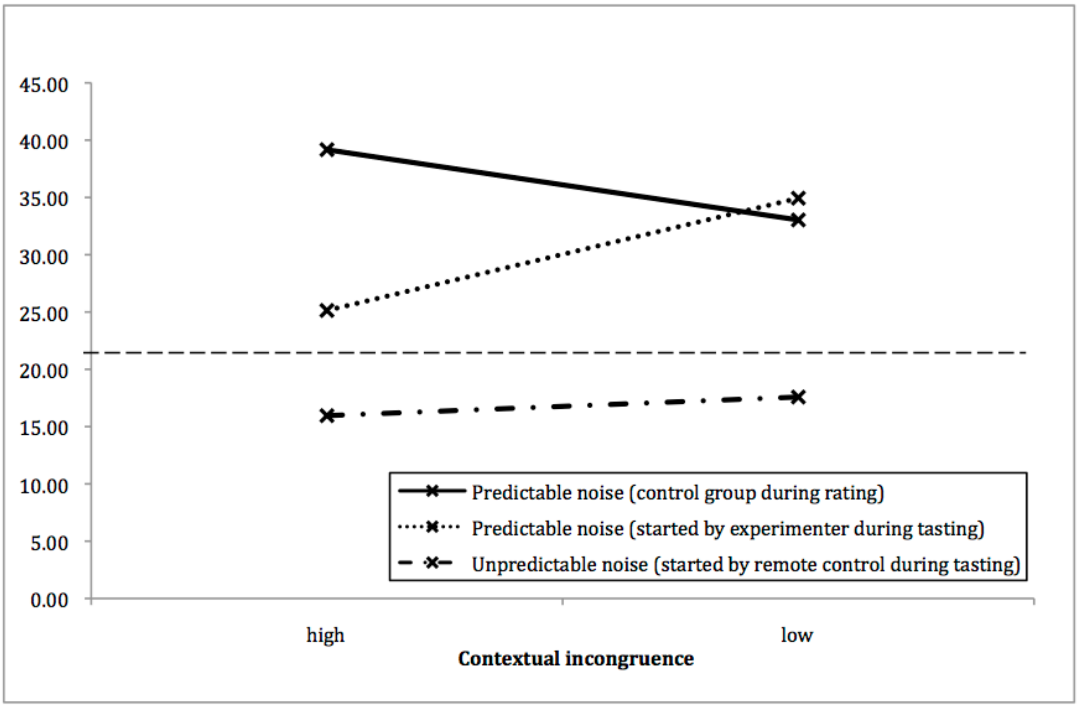

Figure 8. A preliminary predictive agile applied soundscape framework for non-participatory observation methods and psychoacoustics. The model can be used in the context of urban sound planning methodology and developed in order to provide more robust predictive outcomes for specific use cases.