Soundscape Ecology:

The Effect of Environmental Noise Levels on Soundscape Perception in Urban Environments

Abstract

This research is an inquiry into how industrial noise levels in urban environments affect the psychoacoustic perception and personal preference of a given soundscape. A thorough definition of the term *soundscape ecology* is provided at length (especially within the context of an urban environment), subsequently followed by a presentation of research findings which indicate the significance of the soundscape in the context of acoustical perception in urban settings. Through this extensive inquiry into research pertaining to ecology, anthropology, and acoustics, it can be discerned that the expected, behavioral sonic qualities of the discreet objects which compose the entirety of an urban environment, the spatialization of these objects in relation to one another, and previously acquired level of environmental sound experience, are some of the most significant factors in determining an individual's overall subjective acoustical comfort level. However, with the idiosyncratic nature of such subjective test results, being able to scientifically specify the exact natural or industrial sonic qualities that affect individual acoustical comfort has proven itself to be a challenging endeavor. While it it is possible to make

concrete conclusions on the overall soundscape preferred by the majority of the global city-dwelling population, the discreet factors that lead to these preferences are wide ranging and highly dependent on metrics proven to be difficult to contextually quantify.

Introduction

Understanding why certain difficulties arise when attempting to make any sweeping scientific conclusions on the subject of perceptual soundscape preference must be predicated with an understanding of the term itself. First attributed to experimental sound artist Murray Schafer (Westerkamp, 2002), the term *soundscape ecology* is actually making reference to a holistic cognitive process that includes a perceptual understanding of a highly contextualized acoustical environment embedded within a broader manmade or natural setting (Truax & Barrett, 2011); while associated with aesthetic disciplines such as sound design and music production, the term is not referring to any particular instance of a genre or group of sounds, but rather is a descriptor that can be utilized to represent the end result of the myriad of individual processes involved in sound perception and acoustical analysis. Chief among these perceptual processes is the necessity of developing a listening context around the surrounding environment, as it is only after a personalized familiarity with a surrounding area has been developed that the individual can then place sonic expectations upon their present conditions (Davies et al., 2013*).* Therefore, studying soundscape ecology from a purely scientific standpoint provides an incomplete perspective into how an individual interacts with an acoustical environment.

The immediate importance of soundscape ecology can be observed in the interdisciplinary way in which the study must be approached, as its multifaceted domains connect a myriad of academic studies, scientific professions, and artistic disciplines in an attempt to better understand how to design a city on the basis of acoustical comfort. By consulting with not only acousticians, but with artists, anthropologists, conservationists, and architects, city planers are able to combine scientific study with quantifications from individual social surveys in order to delineate between desirable and unwanted noise. This, in turn, facilitates the separation of excessively loud regions of the city with the more sought-after residential areas. A practical implementation of this interdisciplinary collaboration is the now-standardized practice of positioning an airport, shipping port, or high volume area of commerce far in proximity from suburban homes and neighborhoods.

However, most modern urban environments have exceeded the space for which they were once originally planned to occupy, resulting in far less prospective land for future expansion (Hiramatsu, 2004). For this reason, sprawling suburban areas are far less common in cities than rural areas (or outside of city limits), as expanding upwardly is considered to be the more viable option for many places around the world. This upward expansion causes these aforementioned professionals to approach the problems associated with excessive industrial noise as a process of reduction, rather than one of geographical separation. Through comparing SPL A-Network measurements taken from around the world, acousticians are able to construct Isobel Noise Mappings, which are sophisticated data representations indicating "an existing or predicted noise situation…indicating breaches of any relevant limit value in force, or the number of people affected in a certain area" (Hiramatsu, 2004). These mappings are used to determine or predict which current and future sound sources will have the most impact in an urban environment, with the whole of the map analogous to an aural representation of how an individual visually interprets a highly specified snapshot of a sonically dynamic ecosystem. Furthermore, noise mapping representations can yield unexpected yet inter-related anthropological information about a city, such as the existing relationship between noise levels and how they closely correlate with the diverse socio-economic, racial, and political sections of a city (Bruce & Davies, 2014).

Due to the inter-disciplinary nature of soundscape ecology, coming to any broad scientific conclusions, nor designing a city based on acoustical comfort, can be accomplished in any practical manner without the indispensable feedback acquired from subject testing. In order to determine the effect of environmental noise levels on soundscape perception in urban environments, constructed sound walk experiments have been conducted into how acoustic researchers from around the world quantify testing for such a subjective result.

Literature Review

Because of the way in which testing must be conducted, it has proven to be difficult in determining which parameters can be quantified; parameters tested for are usually semantically differentiated through psychoacoustic terms rather than reported in a purely scientific, empirical manner (Kang & Zhang, 2010). While a single signal can be adequately described using physical attributes such as its amplitude changes level over time, spectral energy, and temporal envelope, the subject feedback to most soundscapes evaluated within a field test are quantified through primarily semantic metrics - descriptive colloquialisms or phrases that adequately explain the feeling an individual experiences while immersed in an environment, as opposed to using a physical quantification to describe what can be thought of as a perception of an instance of a sound (Hall et al., 2013). One of the numerous reasons for this is that a soundscape is not a single signal but the complex sonic equivalent of a visual landscape (Bruce & Davies, 2014); depending upon perspective, an environment can be experienced interactively as much as it can be witnessed passively.

Through tests conducted in London parks situated closely to industrial development, Hall *et al.* (2013) demonstrated that there are a number of pertinent reasons in opting for this semantic analysis - namely, the fact that most soundscape tests feature a large diversity of individuals of varying age, gender, age, occupation, and level of education. While this guarantees more variance in perspective (a vital consideration when attempting to plan a city), it also diminishes the ability of test subjects to scientifically evaluate the soundscape being experienced in real time, nor would a scientific evaluation be indicative of the way in which these environments would be psycho-acoustically perceived in real time, outside the confines of a partially controlled test. The very factors that guarantee the necessary diversity in a testing field also negate the ability to arrive at many scientific conclusions, as the factors that influence a person's soundscape preference and acoustical comfort oscillate on an individual basis, and are heavily determined by their cultural values and occupational history (Hall et al., 2013). Of all the demographic variance, a key component in understanding how difficult it is to quantify these test results is understanding the role that age assumes in the conducted processes. Age is one of the most significant distinguishing factors in every test, as cultural and consumerist differences in technology greatly affect how someone experiences a specific auditory environment. As indicated through the testing performed by Bruce and Davies (2014) in London and Manchester, technological differences in the populace will translate to significant cultural and behavioral differences, such as walking speed, talking volume, listening volume (of audio devices) and acceptable social customs.

As the myriad of cultural factors influence the perception of a soundscape, it is those very factors that also enable the listener to acquire an expectation as to how an environment is supposed to sound (Yang & Kang, 2005). It has been argued that, over time, listeners grow accustomed to not only how specific objects sound, but how locations (spaces) sound as well. A listener being able to assimilate to a new listening space (for intents and purposes, a “space in this context is a heavily concentrated, urban environment, such as a bustling city street) is contingent on the present space fulfilling the expectations the listener has: the specific noise, sound, music, or signal is not as relevant as each of the specific auditory events meeting a culturally assimilated expectation. This information makes placing an individual’s subjective responses into scientific context very difficult, as an attempt needs to be made to delineate whether an individual is assessing a soundscape in real-time or whether they are reacting to how an environment sounds relative to their expectation of how they think it should perceive itself to behave (Hall *et al.,* 2013). Furthermore, subsequent testing would also indicate that the quantifiable assessment of a soundscape can be further convoluted by a lack of confidence in the way in which a soundscape is being holistically perceived, as there is an uncertainty into whether test subjects are evaluating the soundscape as a collective, singular sound, rather than assessing each sound on its own merits. The issues of soundscape evaluation are exacerbated by the ambiguity involved in testing for how listeners associate disparate emitters within a sound field (Cain, Jennings, & Poxon, 2013), and more specifically, how the balance of near and distant objects influence the acoustical comfort of a sonic environment. Furthermore, the differences in listening presences derived from the aforementioned diversity in the testing demographic age potentially cause a discrepancy in the aforementioned blend of near and far sounds that does not truly exist. Such discrepancies could ultimately alter the the perception of noise levels in a soundscape based on the manner of consumption, rather upon any physically or scientifically observed phenomenon or any psycho-acoustic principle.

The amalgam of learned expectation, perception, identity, and the mode of consumption all coalesce to produce a multi-dimensional, emotional reaction to soundscape ecology (Cain, Jennings & Poxon, 2013). As a result of this realization, numerous tests have been conducted throughout the world that supplant physically or scientific metrics with differential semantics comparisons meant to accurately connate a feeling or emotional reaction associated with each individual sound or collective soundscape. The quantifiable differences in amplitude values were substituted for descriptive words such as “calmness”, “vibrancy,” or “intrusiveness” (Yang & Kang, 2005). Such studies are indispensable, as acoustical comfort is one of the foremost determinants in achieving the desired positive emotional response in any given environment.

Testing for the emotional dimensions proves a challenging endeavor, as it is concerned with evaluating the context of the soundscape and the reactions of the testing subjects as much as the process is concerned with evaluating physical, acoustical qualities (Cain, Jennings, & Poxon, 2013). Kang and Zhang (2010) tested by splitting test subjects into groups based upon age and profession, with the older, more musically experienced subjects in one group, an another group designated for younger subjects with little to no musical or architectural experience. Other tests by acousticians have focused on keeping test group selection a randomized process, exposing them to a variety of urban and natural soundscapes within the same city, while tests conducted by anthropologists often tend to focus on how one's own social behavior affects the perception of noise levels (Hall et al., 2013).

The most comprehensive tests for determining the emotional effect of environmental noise levels on soundscape perception involve a combination of indoor and outdoor sound walk experiments with simulated soundscape environments being playing back in a highly controlled laboratory setting (Bruce & Davies, 2014). Testing in this manner facilitates a comparison between a real world environment and a simulation wherein the test subject could choose which sounds to be included or omitted in a soundscape. Such experiments not only yield practical city planning knowledge by allowing for the observation of test subjects in a realistic environmental setting, but also provided the opportunity to observe the same behavior in a laboratory setting, where acousticians are provided the opportunity to determine which specific sounds are preferred over others while simultaneously having more control over the parameters of the experiment. A laboratory test enables acoustics to control the soundscape in real time, adding or omitting intermittent noises, as well as modulating the output of the sound sources within the simulation.

Analysis and Conclusions

In the case studies included in this research, all of them were primarily concerned with obtaining a semantic differential analysis pertaining to the effect of noise levels in urban environments, quantifying subjective qualities experienced by individuals in comparative urban soundscape settings, as well as determining which specific type of soundscape the overall urban populace preferred. These soundscapes, categorized as either machine-made (industrial noise), human-made, or natural sounds (any other sound made by an animal, or objects observed in nature), were experienced as either sound walks or controlled laboratory installations which were then followed by a survey or focus group analysis (Bruce & Davies, 2014).

Based upon multiple semantic differential analyses conducted around the world, it can be determined with confidence that urban populaces overwhelmingly prefer “natural” soundscapes over any other acoustic ambience, while noise-based soundscapes were the least preferred. (Hall et al., 2013), with some tests showing the disparity as eighty-seven percent to twelve percent, respectively. However, the same test case argued that this is only the case as the result of over fifty-five percent of the population now living in large cities (Cain, Jennings, & Poxon, 2013). Of the emotional factors influencing personal preference, the amount of time spent in each acoustical environment is a pertinent one for the obvious effect it would have regarding soundscape preference. Whether individuals truly prefer natural sounds to industrialized noise, or if it is a matter of experiencing industrial noise far more often than natural sounds is still speculative and based on the subjective idiosyncrasies observed within each individual. It is also imperative to take into consideration the notion of city planners judiciously deciding to decouple parks as much as possible from heavily industrialized areas, and how this intentional placement may affect soundscape preference (Truax & Barrett, 2011) .

Certain demographical conclusions could be made as well, as every test indicated that the older and more educated a person is, the less likely they are to prefer industrial noise to natural (or what are referred to as “cultural”) sounds: sounds associated with human interactivity without the aid of industrialized noise (Kang & Yang, 2005). Younger test subjects did not so much prefer industrial noise as much as they did not allow the noise to have such a profound effect upon soundscape preference. In the tests conducted in London and Manchester, ninetythree percent of test subjects over the age sixty-five preferred the natural sounds, while only forty-six percent of test subjects from the ages of ten through seventeen preferred the same sound walk (Kang & Zhang, 2010). This was initially attributed to the relative loudness difference between the industrial and natural sounds, which can also be related to the aforementioned differences in technological consumption among the various age categorizations.

That the primary findings in nearly every test indicated that human test subjects preferred the human and natural soundscapes over the soundscape featuring machinery ambience was an expected, partially intuitive outcome; ample research from other experiments already supported this conclusion. However, what was surprising about subsequent findings was the realization that context plays a vital role in the preference of one sound over another (Hall, et al., 2013). Furthermore, the way in which a specific auditory event is experienced can greatly affect how "pleasant" a sound is deemed to be. Hall *et al.* (2013) detail how a recording of a street food vendor yelling was not deemed off-putting because of the contextual ambience which was simultaneously perceived. Such a vibrant burst of vocal noise, in a vacuum, would be considered excessively loud simply because this commonplace act would be occurring in an unexpected or undesirable context. Therefore it can be determined that the overall amplitude or loudness level, nor sound pressure level from a signal is not the sole determining factor in soundscape preference (Bruce & Davis, 2014). Rather, it is the loudness of a signal relative to the expected context in which it is thought to have been perceived.

While it initially may seem paradoxical, the absence of machine sounds in an urban environment would negatively affect the perception (or at least alter the hierarchy of listening preferences) of the unrelated natural (animal, weather) and human-made sounds. Living in a city without the attributed industrial noise would be a cognitively disturbing phenomenon, as aural and visual cues combine to make up the majority of the sensory information required to accurately localize oneself within a given environment. (Cain, Jennings & Poxon, 2013); it would be nearly impossible to cognitively dissociate one from the other in any practical sense. Furthermore, results indicated that the level of expected loudness and spatial balance greatly affected the soundscape listening experience (Bruce & Davies, 2014). Sounds can be categorized psycho-acoustically as being independent actors or a faction of a larger, constantly changing soundscape (Westerkamp, 2002). The factors are that affect this categorization are one's own previous passive and non-passive listening experiences, the loudness level of a particular sound relative to the other sounds within a soundscape, and the behavior of any given object relative to how the object was expected to behave.

Pertaining to spatial balance, one of the primary determining factors in whether a soundscape was deemed as "good" or "unpleasant" in the post-soundwalk surveys was the way in which foreground and background noises interacted with each other (Davis et al., 2013). When there was the presence of depth within the a well balanced acoustic mix, the soundscape was categorized as being "good", simply by objects sounding the way in which subjects expected them to sound relative to their interaction with them. However, unbalanced, overly amplified sounding the foreground (such as an overly loud air conditioner or pump) would take the listener out of a their sense of well-balanced immersion. This is analogous to the way in which music mixes are subjectively assessed by audio engineers and casual listeners alike.

Similarly to the subjective interpretation of a music mix, it is impossible to eliminate the unique contexts through which an acoustical environment is experienced, nor would it be advisable to test under such uniform conditions, as the development and recognition of acoustical contexts by a test subject (the listener) is the content that translates into developing learned sonic expectations for the given space; the amalgam of learned expectation superimposed over a highly contextualized listening space is the determining factor in soundscape preference (Hiramatsu 2004). Noise levels greatly influence soundscape preference, but only to the extent that certain listener expectations are met with respect to contextual awareness, spatial balance, and collective experience. Although loudness differences ins city can be thoroughly mapped through quantifiable means, evaluating how industrial noise levels affect the acoustic comfort level of a populace cannot be explained in a completely scientific matter, as the synthesis of one's current auditory environment never occurs in a vacuum, but rather through a dynamically altering, subjective aural prism.

Future Considerations

Identity and demographics will always have massive influence over the evaluation of soundscapes. As cities increase in size, they also increase in racial and ethnic diversity. As the diverse of a city increases, city planners need to be sufficiently informed on the noise-specific issues that may arise in a neighborhood where the majority of the population consists of under-represented minorities. As a result of such low racial representation in the soundscape surveys, city planners are ill-equipped to adequately address any noise level discomfort that may come as a result of living in these communities - an arrangement that ultimately contributes to the lower standard of living and acoustically comfort experienced in impoverished communities (Hiramatsu, 2004). While age happens to be adequately represented, greater inclusion into the test subject pool regarding race and socio-economic background could greatly improve the soundscape design of certain disadvantaged communities throughout the world, thus leading to an overall improvement in the acoustical comfort level experienced in each respective city.

There is also the potential for demographics to be crossed referenced with the feedback received by other soundscape surveys conducted around world. An interesting experiment would be to synthesize a natural, industrial or human-made soundscape from one region of the world and have the test subjects all come from a completely different geographical location. A prospective example of this would be acousticians simulating soundscapes from downtown Tokyo for a group of test subjects from the middle of the United States. Since the subjective response to noise levels within a soundscape is largely predicated on expectation and exposure, placing individuals in a completely unfamiliar context would yield potentially unexpected preferences.

City planners and acousticians need to develop testing methods for as many diverse urban sound settings as possible, as the majority of sound walk surveys only account for the noise level effects in either isolated parks or on crowded industrial city streets. How the noise levels in these well-researched soundscapes compare to the acoustical comfort levels of other, less-documented urban settings such as warehouses, in-city amphitheaters, or underground transportation systems, is yet to be determined. More research is also needed regarding the perception of spatial presence within these undocumented spaces as it relates to soundscape preference and acoustical comfort.

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