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Soundscaping health

Resonant speculations

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Abstract

Among the challenges arising in the fields of Acoustic Ecology and Sound Studies is the often contentious process of defining soundscapes that promote health. Questions arise: Should recommendations be based on individual preference, or are there universal principles that apply regardless of circumstances? Are there such things as toxic and nourishing sounds, comparable to elements of nutrition? Do R. Murray Schafer's calls for quieter and more harmonious soundscapes still make sense amid new assessments of urban noise as a vector for intercultural communication? Are both stances due for reconsideration?

Decades of medical research on the effects on health and mood of ambient noise and recreational music can provide answers to some of these questions, even as studies from the social sciences raise others.[1]

Introduction: Noise and nostalgia

Since Canadian composer and educator R. Murray Schafer first defined the founding principles of the Acoustic Ecology movement in the 1960s and 70s, the concept of soundscaping has gradually gained attention in the fields of environmental design and healthcare. Soundscaping, which alters the ambient sounds of a natural or built environment, can involve the conscious designing of engineered sonic elements based on measurement and analysis of existing patterns, or the addition of new patterns – mechanical, musical, recorded and/or spoken – to what is already present. It can also involve the masking[2] and muting of undesirable sounds. Its original purpose within the literature of Acoustic Ecology was to improve soundscapes, usually by making them less abrasive, less 'noisy' and more appealing.

Schafer's book *The Tuning of the World* (1977) followed excursions into the history of noise and music with a chapter entitled 'The Acoustic Designer' in which he blamed the 'sound sewer' of late 20th-century Western society on neglect of listening and on 'impassioned devotion to machines' (p. 237). His recommended remedy for urban noise was acoustic design, based in knowledge of the structures of natural soundscapes and in the preservation of unique and informative 'soundmarks' – characteristic sounds associated with specific places and cultures – that distinguished particular cities and neighbourhoods from others: everything from the distinctive scraping of chairs on the floors of Parisian cafés to the trams in Melbourne and harness bells on horse-drawn Turkish taxis.[3] Schafer's suggestions for soundscape improvement included redesign of urban crosswalk signals, train announcements and phone ringtones in more melodious manifestations, emphasising his belief that architects, design engineers and composers should collaborate on the optimisation of urban soundscapes.

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The quest for ideal soundscapes as defined by the early phases of the Acoustic Ecology movement was based in the belief that quiet surroundings and 'natural noise' – primarily birdsong, rain and flowing water as well as the sounds of traditional non-mechanised human activities – had the potential to return people to a pre-industrial state of tranquillity as well as to protect their hearing. Decades later this desire seems chimeric. As critics of the Acoustic Ecology movement's aesthetic goals have pointed out in this journal[4] and others, urban environments have never included extended periods of melodious sound or silence. Legal and literary records from ancient Rome through 18th-century Europe occasionally describe the noises – rumbling market wagons, thudding machinery of water and wind mills, metalworkers' hammers, night-brawling tavern patrons, street musicians, quarrelling neighbours, roosters, babies, dogs – common to urban venues in pre-industrial Europe. Industrialisation and motorised transportation changed the sonorities, but not the association of population density with random, annoying and often loud sound.

Noise and neuroscience

Rather than a nuisance, could ambient urban noise be the *lingua franca* of progress? Acoustic sociologist Brandon Labelle's work on urban soundscapes and their significance for the future of communication and social interactions among diverse cultures provides crucial insights about the function of noise as a disturber of the social boundaries that inhibit intercultural communication. '[S]ilence is a slippery ideal as it gathers within the imagination a set of seemingly positive values that when overlaid onto social behavior and community lends to understandings of place and placement a contentious intolerance' (Labelle, 2010, p. 55). Historically associated with elites, 'silence' became a vaguely defined ideal for the modern middle class, one of a series of fantasies projected onto suburban life. Labelle attributes the quest for communal silence in the suburbs and the preference for self-contained, exclusive and culturally segregated residential districts to a kind of anti-urbanism interwoven with fear of ethnic, racial, economic and linguistic diversities. To him, the city is an amplifier of interaction among individuals and cultures; hearing each other at close proximity forces us to communicate, whether by intention or through conflict. It is through self-proclamation and confrontation that we learn to recognise the value of diversity, he concludes, and if everyone kept quietly to themselves there would be little progress towards real understanding. This perspective turns sound and silence into metaphors for social interaction or its absence without accounting for the very real physical consequences that result from pervasive noise. In a reversal of the accustomed scale of status, it gives the advantage to the urban milieu by regarding quiet as a type of poverty.

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The interpretation of urban ambient noise as a desirable vector for intercultural communication is thoroughly valid within the contexts of communication theory and urban sociology; it is perhaps less so when real-world statistics on noise-induced hearing loss, stress, and sleep and learning deficits are factored in. The World Health Organization (WHO) concluded from research carried out in the 1990s that a combination of ambient urban noise and unprotected occupational noise exposure was a growing global health problem (WHO 1999). Subsequent studies motivated by the WHO conclusion showed that ambient noise, particularly for residents close to an airport or a major highway, slightly but significantly elevated the risk of increases in blood pressure and stress hormones, muscle tension and sleep deprivation (Haralabidis et al., 2008; Jarup et al., 2008).

Other reactions, less well studied because they are harder to quantify, include emotional, cognitive and psychological symptoms like distraction and anxiety. These are related to stress hormone and neurotransmitter levels, but also to the idiosyncratic sensitivities of individuals to what is deemed noise annoyance: a reaction to persistent ambient noise at low or moderate levels of loudness. Even when ignored, ambient noise is subconsciously registered as a source of warnings about potential danger by the nervous system, because our remote ancestors had to react quickly to the subtle sound of an approaching predator or snake in order to survive. Today, machine noise that mimics the growls, roars and hisses of wildlife hazardous to hominid survival is ubiquitous in factories and common even in the ventilation systems of apartment and office buildings. Despite modern knowledge of the mechanical sounds' benign sources, human stress levels can rise just enough to produce tensed neck muscles, headache, fatigue or a vague feeling of irritation (Weinstein, 1982; Cacioppo & Gardner, 1999; Kalveram, 2000; Ouis, 2001). The evident harmony of Schafer's ideas with the 'back to the land' movement of the 1970s counterculture may now seem excessively idealistic, but it contains observations worth reconsideration at a time when the majority of people worldwide live in cities and are subject to the small quotidian stresses of noise annoyance.

When noise annoys

We know from a vast literature on research done by the noise abatement industry that there are particular sonic properties associated with annoying noise, specific acoustic and auditory conditions that will produce a sense of irritation in anyone with healthy hearing. These have to do with the acoustic properties of the sound, its perception and interpretation by the auditory system and the conscious associations and unconscious effects that it evokes.[5] Extremes of loudness, duration without variation and proximity to sources are most likely to be involved. A frequency range[6] between 2,000 and 5,000 Hz – equivalent to the highest keys on a piano – can

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also be irritating, especially when prolonged. However, the first quality that people are likely to notice about sound is how loud it is. Loudness is actually the amount of pressure exerted by a sound wave on air, its consequent impact on the eardrum and its subsequent conversion in the auditory system to signals that activate the brain.[7] If the pressure of a sound wave is extremely low, the sound may be hard to hear distinctly, unless its ambient background is very quiet. If the pressure is high, it will grab attention. If extremely high, the pressure will produce pain and damage the delicate nerve cells of the inner ear, leading to loss of hearing acuity.

Noise-induced Hearing Loss (NIHL) comes about when the tiny 'hair cells'[8] that line the cochlea of the inner ear and vibrate with the stimuli of specific frequencies are flattened, frayed and eventually broken by excessive sound pressure. For most who experience it, the first noticeable symptom of NIHL is tinnitus: a persistent ringing or buzzing sound caused by sound pressure trauma to the inner ear and the auditory nerve that carries cochlear signals to the brain.[9] Repeated exposure to loud sound – noise or music – will result in loss of ability to distinguish speech from background sound as well as degradation of the ability to hear the high-frequency components of both music and speech, including the voices of women and children.

NIHL is typically a gradual process that used to be associated with advanced age and industrial work. Since the 1970s, however, a combination of portable audio players – radios, Walkman and Discman players and then mp3 devices with in-ear transmission – and changes in the technology of amplifiers for concerts have made recreational listening both possible and common at hazardous levels of sound pressure. Researchers reported as early as 1993 that 65 per cent of the volunteers they surveyed and then tested with pure tone audiometry, all young males aged around 25, had damaged hearing acuity, comparable to that of much older men (Spaeth et al., 1993).

The determination of ideal soundscapes, then, begins with awareness of what is not ideal: Persistent abrasive sounds cause annoyance even when ignored, and extreme loudness causes physical harm. However, this observation fails to explain the passionate popularity of loud music, whether in entertainment venues or inserted directly into ear canals. What potential benefits and harms result from the lure of the loud? Are there such things as sonic toxicities and addictions?

Sonic toxicities: Questions and answers

The definition of sonic toxicities in light of physical harm is clearly established. Excessive loudness is harmful, and what is excessive can be clearly determined by the sciences of acoustics and auditory physiology. Definition in the realm of psychoacoustics – the science of interpretation of, and responses to, sound – is far less clear. Individual responses to sound range from spontaneous to conditioned, with

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considerable influence from cultural traditions and expectations, emotional history and even the physiology of skulls and ear canals. How, in this complexity, are the benefits to be identified?

Technology further complicates questions about harmful and beneficial sound. Portable listening devices enable listeners to carry playlists and podcasts onto city streets in order to enhance or mask the urban sonic ambience of traffic and construction. Studies of listener responses to these technologies emphasise freedom to construct both identity and emotional safety through mobile listening (Bull, 2000, 2004, 2007) as well as the ability to craft creative soundtracks by using recorded music or speech as counterpoint to ambient noise (Kaye, 2013). The ability of portable audio to provide instant personal control of a sonic environment means that no intrusion by strangers or interruptive noise need be endured; its reliable provision of mood support means that a stressful commute or period of waiting can be transformed into pleasure and even into art.

It is worth noting, however, that the components of a soundscape – indoor, outdoor or electronic – are registered by the auditory system whether or not they are given attention because of the evolutionary importance of their signalling functions. The crafting of personal soundtracks may therefore carry a certain responsibility: Its classification as an unquestioned good is due for some adjustment because of NIHL risk. Listening through in-ear devices, while safe at moderate loudness levels, becomes a hazard as soon as the listener has to contend with layers of noise from construction sites, exercise machines at the gym, appliance motors at home or the daily train commute. Turning up the volume in noisy conditions while listening through speakers located within millimetres of the eardrums raises the risk with prolonged or habitual use.

The WHO now estimates that 1.1 billion people worldwide, mainly teens and young adults aged 12 to 25, are at risk of hearing loss and its consequent effects on education and employment options as a result of excessively loud recreational listening devices as well as performances and sporting events (WHO, Media Centre, 2015).[10] It was first reported that one hour of listening at 70 per cent of total volume on conventional headphones available in 2004 would equal the maximum permissible noise exposure for one eight-hour workday. Using inset earphones (earbuds) would decrease the safe time span considerably and unpredictably, since manufacturers' standards were variable. A limit of one hour per day at 60 per cent volume was recommended to protect hearing (Fligor et al., 2004), although compliance with this limit was – and is – unlikely.[11] Studies in Europe and China in subsequent years confirmed the hazard (Peng et al., 2007; Cassano et al., 2008; SCENIHR, 2008). A more recent study found that the maximum settings for mp3 devices can now reach 126 dBA, and that 40 per cent of test volunteers chose levels above 94 dBA, well over 60

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per cent of the maximum, when listening over a noisy background (Breinbauer et al., 2012).[12]

The lure of the loud

Loudness has become a symbol of the youth culture that dominates the music industry, and a vast machine for generating profits. As the volume levels of portable devices have increased, so have the technology for amplification at performance venues and audience demands for more extreme loudness. Decibel levels at continental European clubs and rock concerts a decade ago were measured at levels between 104 and 112 dBA (Bohlin & Erlandsson, 2007). Measurements taken in the UK in 2012, two years after the passage of regulations that limited average levels to 85 dBA, ranged from 105 to more than 115 dBA (Barlow & Castilla-Sanchez, 2012). This range of measurements puts some music events at the level of jackhammers and emergency sirens: Unprotected exposure for 15 minutes during a single event will result in flattened or frayed cochlear hair cells; longer attendance will produce permanent damage. Aggressive amplification is even featured in publicity for large-scale outdoor rock festivals as bait for audiences (Barlow & Castilla-Sanchez, 2012).

Whether the venue for an event is indoors or out, multiple speakers engineered for high decibel levels ensure that the sound produced is a form of power, catalysing physical and emotional release while endangering hearing. Average nightclub levels were estimated in one study at 98 dBA with typical exposure times of up to five hours (Williams et al., 2010). Another survey conducted in the UK on 357 university and medical students who regularly attended nightclubs showed that 88 per cent reported tinnitus immediately afterward and 66 per cent reported impaired hearing the next morning (Johnson et al., 2014). Despite knowledge about the effects of excessive amplification levels, the majority of club patrons (73 per cent) reported no intention of changing their listening habits.

What is the attraction of sound so loud it causes tinnitus and even pain? In a presentation for the Ninth International Congress on Noise as a Public Health Problem, architectural soundscape researcher Barry Blesser (2007) confronted the question of benefits from extremely loud noise and music: Given the hazards to hearing, why are so many people attracted to deafening sound? Along with recognising the appeals of social distancing and ownership of personal space, he summarised research on the neurological impacts of loud sound to demonstrate another conclusion: Like alcohol, drugs and sex, extremely loud music alters consciousness. It brings the entire nervous system into a state of excitement, stimulates the brain to release endorphins and can even produce addictive responses in habitual listeners (Blood & Zatorre, 2001; Schmuziger et al., 2012). Sound above 90 dBA, particularly when paired with rhythm and inclusive of low frequencies, sends the vestibular

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system of the inner ear, responsible for balance, into high alert (Todd et al., 2000; Blesser, 2007). The resulting disorientation drives away conscious thought and opens the possibility of acting purely on impulse, heart pounding and body driven to dance. A paradox results: emotional benefit pitted against harm to hearing.

Music, mood and medical research

Can the association of music with sonic toxicity go beyond decibel levels? The risk of physical harm from music results from its loudness rather than its content: Classical music played at 90 dBA will produce NIHL faster than heavy metal at 70 dBA, and professional symphony musicians whose instruments are held close to an ear use specially designed earplugs to preserve their hearing: violinists in the left ear, flute players in the right, anyone seated in front of the trumpets in both. The question of subtler forms of harm is still open, however, because understanding of the psychological effects of music is still in its infancy. Growing knowledge of the effects of music on emotional states will lead to better understanding of the effects of other acoustic conditions: speech, noise, natural ambient sound and quiet.

A common suspicion among researchers is that musical styles characterised by discordant harmonies and aggressive sound qualities – hard rock, heavy metal, punk, emo and their offshoots – might be detrimental to health, while mellower and more concordant styles – classical, folk, jazz, country and easy listening – are beneficial. Some examples of medical research can serve to focus the questions that arise from attempts to categorise music as explicitly harmful or therapeutic. One small-scale pilot study that compared musicians with a control group of non-musicians found that music with a fast pace – regardless of style – 'significantly increased' heart rate, respiration rate and blood pressure in both groups, with stronger effects in the musicians. The effects decreased, however, when silent pauses were randomly inserted between rounds of listening (Lin et al., 2011).

Assumptions about the effects of particular musical styles have not been verified by research. This is in large part because two different models are used to assess healing properties of music. In medical research the gold standard for benefit is stress reduction, with its attendant properties of lowered blood pressure and decreased production of stress hormones. The literature of music therapy, however, does not limit the definition of healing to stress reduction. Along with relaxation, its practitioners regard stimulation of activity, increases in communication skills and sociability, and acquisition of musical skills as cherished goals. Music therapists believe that any musical style preferred by a client can be beneficial to them, and that assigning 'therapeutic' music can be counterproductive if the client has no positive emotional connection with the music being presented, either because it is unfamiliar or because it has unpleasant associations for that individual. In their

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model even heavy metal can potentially have therapeutic uses as a goad to emotional expression in those who identify with its culture, although in some listeners it can lead to feelings of isolation and anxiety (McFerran & Saarikallio, 2014).

Research findings also imply that music designed to induce particular states, whether stimulation or relaxation, does affect the human nervous system in measurable ways, and that music can change mood. One small study found that either classical or self-selected familiar music effectively returned test subjects to a state of emotional and physiological equilibrium after exposure to a stressor, where silence or listening to heavy metal music did not (Labbé et al., 2007). Another compared responses to classical and techno music, finding that techno produced feelings of tension, urgency and anxiety as well as increases in blood pressure, heart rate and blood hormones. After listening to classical music the same participants reported feeling relaxed, although physical responses did not show significant change from measurements taken without music (Lin et al., 2011). Even the discovery that loud discordant songs with violent lyrics increase feelings of anger and aggression – although not *acts* of aggression – warrants further examination. A study focussed on the issue concluded that such effects appear to be transitory and likely to leave the accustomed listener more relaxed afterwards, although the style might alarm listeners unaccustomed to it (Sharman & Dingle, 2015).[13]

Research in this area is still preliminary: Studies published thus far have relied on small numbers of participants, primarily university and high school students, and many do not report sufficient detail about the music used.[14] They are significant, however, in bringing legitimacy to musical taste as an area for scientific study and providing a window into the complexity of psychoacoustic responses. They also point the way towards new methods for measuring the effects of listening on cognition and emotion. Although the spectrum of evidence is incomplete at this time, some tentative conclusions can be drawn from current literature on emotional responses to music:

- that the biochemical and other physical markers of stress, as well as feelings of distress and anxiety, can be reduced by music designed to induce calm and rational states;
- that aggressive and abrasive music can be disturbing to unaccustomed listeners, but may have selective therapeutic potential as an aid to awareness and diffusion of negative emotional states;
- that music familiar to the individual, perhaps regardless of style, can be beneficial.

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Far more research is needed in order to develop valid paradigms, and even these may or may not be universally applicable. It is essential that such research be done in order to provide evidence of benefit as well as harm.

Sonic nutrition: Speculations

What might comprise a nourishing, or even healing, soundscape? What sounds provide sustenance? If being conscious of what we eat can contribute to physical health, can conscious listening, to natural soundscapes as well as carefully constructed soundtracks, contribute to emotional well-being?

Awareness of health and harm in nutrition can provide one potential model for the development of health-promoting sonic environments. The North American addiction to the convenience of processed food, beginning with post-war acceptance of cake mixes and packaged breakfast cereals, grew for decades into the fast food industry that now dominates urban habits of consumption. Now that research on nutrition is providing information on the mechanisms by which food sustains or damages physical health, and now that there is extensive literature – both popular and scientific[15] – demonstrating the dangers to health and detriments to productivity that result from the consumption of industrialised fast food, questions are being raised and 'slow food' is gaining credibility.

The Slow Food movement was founded in 1986 in Italy as a protest against the encroachment of the McDonald's chain on traditional Italian food culture. It concentrates on nutrient-rich 'from scratch' home cooking and on eating of fresh, locally-grown ingredients, as well as home and community gardening. Slow Food is a dialectical reaction against processed pseudo-food, but also against the social habits of speed and inattention to detail that characterise the driven Western urban life. It is convivial, individualistic and nostalgic for a time before the invention of convenience foods. The intention behind it, however, is not to drive women back into kitchens as full-time managers of the food supply. Slow Food encourages everyone – women, men, children, communities – to learn about food production, selection and preparation, and to regard food as an art form as well as a necessity. Rather than a call to recreate the past, it is an encouragement to learn from the past about how to improve the future by attempting to solve the problems associated with fast food – poor nutrition, obesity, diabetes and hypertension – by means of local and home production of nutritious food.

The Roots of Change organisation in California exemplifies Slow Food's progress from a protest group to a genuine movement with broad support. Their website, rootsofchange.org, provides information about food and farming policies in the United States and advocates for sustainable practices, for support of organic farming and for the establishment of fresh local produce markets in urban 'food deserts'

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served only by large-chain supermarkets that encourage the consumption of processed corporate convenience foods and of produce imported at high cost and low nutrient value.[16] The movement also catalyses public support for legislation to improve nutritional options in low-income urban neighbourhoods (Clark, 2015).

Parallels between Slow Food and Acoustic Ecology are easy to find. Among the practices supported by Slow Food enthusiasts worldwide is the preservation of traditional farming methods and of heritage seeds and livestock breeds. These efforts are analogous to the Acoustic Ecology movement's desire to preserve or restore quiet places in order to sustain population health by combatting noise-induced stress. Through advocacy of conscious eating and conscious listening, both movements are promoting awareness of emotional nutrients as well as physical ones.

Tuning a future?

Like the alliance of Slow Food with organic farming and gardening, the quest for sonic nourishment is expanding its focus to include natural sound. The soundscapes of industry, technology and commercialised entertainment now dominate the experience of billions of people worldwide, removing attention from the soundscapes in which our species evolved and developed its cultures, and from which it is still capable of drawing comfort and reassurance. Such acoustic surroundings gave our ancestors information as well as a matrix for language and music, foundations of culture.[17] Losing connection with them removes us from our biological roots and leaves us confused about our common heritage as a species: *homo audiens*.

Exposure to natural soundscapes has long been recognised as a way to promote relaxation, and new medical evidence is just beginning to catch up with common knowledge. One pilot study on rates of nervous system recovery from a stress-inducing mental task followed the task with either recorded noise at 40, 50 or 80 dBA, or with recorded sound from a fountain and birdsong at 50 dBA. The research team concluded that 'after psychological stress, physiological recovery of sympathetic activation is faster during exposure to pleasant nature sounds than to less pleasant noise of lower, similar, or higher sound pressure level' (Alvarsson et al., 2010, p. 1044). Recordings of rain, rivers, waterfalls and birdsong were shown in another study to decrease anxiety in 140 patients recovering from open heart surgery. The team recommended use of such recordings as a non-invasive and cost-effective way to facilitate healing and reduce the need for anti-anxiety medications (Aghaie et al., 2014). Medical researchers often conduct studies of this type, more because they are motivated to reduce healthcare costs than to promote particular therapies, but through their efforts evidence of beneficial sonic environments is growing.[18]

If recordings of natural soundscapes are showing benefits to health, what about the soundscapes themselves? It is tempting to speculate that live immersion in

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natural soundscapes would produce clear healing responses, but evidence is scarce because of insufficient data. Responses from visitors to remote wilderness areas would be difficult for researchers to gauge because of the time and distances involved as well as the influence of cultural assumptions. However, a survey conducted in Sheffield, UK in large urban parks gave some preliminary hints about the effects of contact with natural areas. While most visitors reported exercise or children as their initial motivation for visiting a park, a survey taken as they left showed that a majority mentioned 'relaxation' as the main effect of their time in a natural setting (Irvine et al., 2013). Soundwalking in parks and wilderness areas, another practice advocated by the Acoustic Ecology movement, might therefore warrant the attention of healthcare researchers for its potential to enhance relaxation and combat stress.

The Acoustic Ecology and Sound Studies movements have grown in the 21st century into a promising matrix for public education about the influence of soundscapes, whether public or personal, on population health. Disputes about the values of noise and quiet echo current re-evaluations of urban sprawl, economic competition and globalisation as well as industrialised nutrition. Rather than continuing to take sides by criticising the movements' origins or succumbing to nostalgia, let us all consider a fact: Urban and industrial soundscapes are too loud, and so are many recreational habits. If the WHO considers that to be a problem for public health, we as scholars of sound should pay attention. The rift between Acoustic Ecology and Sound Studies is counterproductive; I am hoping we can all get beyond it.

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Notes

1 Brief parts of this article are excerpted from sections of my forthcoming book, *Living with Noise: A Listener's Guide.*

2 Masking describes the tendency of multiple layers of sound to blur each other's perceptual impact. A common example of intentional masking is the production of electronically generated neutral sound in open-plan office buildings to shield the confidentiality of conversations: The speech is still present, but goes unnoticed because the soft roar of engineered background noise prevents individual words from being heard. Cancelling of a sound requires determination of the wave pattern for the target sound, then setting up a second wave pattern – identical, but reversely phased – that provides exact opposition, peaking where the first sound troughs and vice versa. The oppositional patterning reduces the sound pressure of the original wave. It is a technical remedy used in the recording and noise abatement industries as well as in noise-cancelling headphones.

3 The book's second edition, published in 1994, does not update the list of soundmarks given on p. 240, although at least some of them had probably changed by then.

4 See, for example, Groth & Samson (2013).

5 For examples, see the website *Engineering Village*: http://www.engineeringvillage2.org/home.url?acw=&utt=

6 Frequency – which indicates how 'high' or 'low' a tone is – is actually a measurement of a sound wave's speed in cycles per second, with faster waves perceived as higher tones. Frequency is measured in Hertz (Hz), named for Heinrich Hertz, the discoverer of electromagnetic radiation; measurements indicate how many times a given sound wave completes a cycle in one second of time. Human hearing, on average, is attuned to frequencies from 20 to 20,000 Hz in childhood, with gradual attenuation of the highest frequencies in adults. Both natural and mechanical sounds usually consist of multiple frequencies that can reinforce or mask each other.

7 Sound pressure is measured by a sound level metre and represented by the decibel system. Decibel readings are given as a number and usually followed by the abbreviation dBA or dB(A), indicating the 'A-weighted' scale of measurement, which is calibrated to approximate the range of human hearing.

8 'Hair cells', more correctly called cilia, are hair-shaped sensory cells that line the basilar membrane of the cochlea in the inner ear. They are linked in groups that vibrate to specific frequencies and convert the mechanical energy of the vibration into signals transmitted by the auditory nerves to the brain, where the signals are interpreted as sound.

9 Brief intermittent tinnitus can also occur with migraine, sinus infection or allergic reactions that affect the sinuses or ear canals.

10 In my own experience teaching an undergraduate course in acoustic communications at the University of Calgary in Canada, approximately 10 per cent of each class reports tinnitus and/or compromised hearing attributable to listening habits. The number may well be higher, since disclosure is voluntary and students are not tested.

11 Hearing-health education programmes were initially reported as largely ineffective for youth (Widén & Erlandsson, 2004). They now show some promise for improving awareness of risks of NIHL among young adults (Keppler et al., 2015).

12 For an example of noise exposure limits, see http://www.noisehelp.com/noise-dose.html. At 94 dBA, one hour of exposure is safe; anything beyond that will produce damage to cilia.

13 Sharman & Dingle (2015) report that it was 'unclear whether the non-fans were angry as a result of the musical characteristics [of heavy metal examples], or because they were being asked to listen to something they did not enjoy'.

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14 For overviews of literature, see Lin et al. (2011) and McFerran & Saarikallio (2014); for findings on the appeal of aggressive music for adolescents, see Took & Weiss (1994). Relevant studies in this area are still infrequent and not always well designed; McFerran & Saarikallio (2014) also comment on this.

15 See, for example, Guthrie et al. (2002).

16 Roots of Change characterises these areas as "food swamps" rather than deserts, due to "an overabundance of highly-processed, unhealthy foods" rather than a scarcity of food: http://www.rootsofchange.org/roc-in-the-news/

17 These observations are central to the work of Bernie Krause: see *The Great Animal Orchestra* and other works.

18 Because research in this area is too new to give valid results yet, questions arise: Are sounds from natural settings more effective *in situ* than recorded? What about birdsong or rain combined with music, or even with distant traffic? Are preferences and healing responses universal or influenced by culture?

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