24th INTERNATIONAL CONGRESS ON SOUND AND VIBRATION
23–27 July 2017, London

The Case For Auraldiversity In Acoustic Regulations And Practice: The Hand Dryer Noise Story

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With its inclusion of "hearing impairments and hearing aids" as factors that may "influence auditory sensation", within the criteria of the new International Standard definition and conceptual framework of soundscape (BS ISO 12913-1:2014), we witness a sea change in how a standard in acoustics may regard hearing: not as a fixed, universal and generalizable metric predicated on the otologically normal (BS ISO 226:2003), but as a shifting, unsteady human trait that we individually, tacitly know from day to day experience. This paper will present a case study that exemplifies the pressing need for such as sea change. It will present the issues arising from a preliminary study of the noise effects of ultra-rapid "ecological" hand dryers in publicly accessible toilets. They are very popular due to impressive data and marketing on efficiency, effectiveness, hygiene and speed, the adverse corollary is a dramatic increase in sound pressure levels in this socially sensitive environment. The study comprised of sound power tests, followed up by in situ sound pressure tests in a range of different sized WCs. The most extreme example from this study showed one dryer in a reverberant public toilet had the equivalent combined Leq of 19 dryers in a free field environment. From provisional interviews it appears that the noise effects are impacting on a wide range of vulnerable subgroups: breast-feeding mothers, infants and children, dementia sufferers, the visually impaired, hearing aid users and most seriously the discomfort on those with hyperacusis and hyperacute hearing in ASD. This study functions as a microcosm for soundscape/environmental noise issues in the urban environment. The paper will conclude with a proposed paradigm for situating hearing in acoustics that extends from a normative, clinical model of hearing, the otologically normal to a socio-cultural concept of the auraltypical and auraldiversty.

Keywords: auraldiverse, auraltypical, high-speed hand dryer, hyperacusis, soundscape

1. Introduction

Core to the discipline (or perhaps interdiscipline) of acoustics, be that the business of sound propagation or mitigation, is the interface between sound stimuli (i.e. external physical world) and human (or animal, an area of greater prominence with the development of bioacoustics but not discussed in this paper) sensation of sound (i.e. the sequence of mechanisms and processes that constitute our auditory system). The efficacy therefore of pretty much the entirety of this practice is based on our understanding and working knowledge of the physics of sound and related materials, our perception and response to sound, and crucially the interrelation of the two. Just as acoustical engineering is reliant on scientific exactitude predicated on universal formulae, precise calibrated measurements, etc. there is an underlying expectation that our understanding of hearing as expressed in the requisite standards can offer equal rigor. It is due to this mismatch between industrial measurements and human response metrics that acoustics is often regarded as out of kilter with other engineering disciplines.

We do have an extant standardised representation of the human sense of hearing that is based on direct experience that offers referable data on frequency and intensity range, and the interrelation between frequency and intensity, *Normal Equal-Loudness-Level Contours* (BS ISO 226:2003), which in turn informs Phons, A-weighted decibels, and so on. This model, directly or indirectly, can be found in the majority of acoustics regulation and practice (aircraft noise, wind farms, building and planning, noise at work, etc.). Its principles hark back to Fletcher and Munson's exploration of equal loudness with pure tones in the Bell Labs in the 1930s (Fletcher & Munson, 1933), taking their lead from Fechner's (after Weber's Law of Intensity) observations in the 1860s, who "addressed the question of how perceived strength depends on physical intensity, stating that the intensity of sensation is proportional to the logarithm of physical intensity, when physical intensity is reckoned in units equal to the absolute threshold." (Florentine, Popper, Fay, 2011).

Equal loudness was not the only approach pioneered in the 1930s; other methods included speed of response, a scale of additivity, a scale from overt judgments of loudness ratios and estimating perceived magnitudes (for details on these approaches see Florentine, Popper, Fay, 2011). According to the Springer Handbook of Auditory Research, "there is a general consensus among psychoacousticians that equal loudness measurements continue to be the 'gold' standard to which results obtained by other methods must conform". (Florentine, Popper, Fay, 2011:32).

Beyond loudness, models of hearing response have developed at pace, and today we have access to the nuanced psychoacoustic models of auditory perception such as sharpness fluctuation strength and roughness, bridging the gap between physical and subjective evaluations. "In psychoacoustic experiments, firm relations between the physical representations of sounds and the correlated hearing sensations are established", states Hugo Fastl (Fastl 2006:1).

2. Whose Hearing?

The salient question in this paper is: whose hearing are the metrics of loudness, roughness and sharpness et al. actually referring to? In an effort to problematise these questions, consider the following everyday case studies:

- The single woman in her 80s, who is enabled by a wheelchair, looks forward to her weekly Sunday church visit, but due to recruitment (a common condition with older people that experience a combination of deafness and a diminished tolerance of loud sounds) the impressive church organ creates unbearable pain. She perseveres however, and sits every week during the service in the adjoining hall.

- An 8-year old boy with Asperger Syndrome attends a normal state junior school. To cope with the classroom noise made by his class mates he is encouraged to wear ear defenders. He loves swimming and diving deep down into the water, where he finds relatively tranquillity. His sensitivity, however can shift from the hyperacute to the hypo – he can become transfixed by the sound of a buzzing light or whirring fridge. When his senses are overloaded, he experiences a sensory shut down.

- The child who has never used a school toilet in his entire schooling due to toilet phobia brought on by an early traumatic experience from the sudden onset of high impact noise from of a high-speed hand dryer in a WC in a public museum.

- The blind man who uses a white cane to aid orientation and scan for steps and kerbs, is exhausted by the insistent torrent of urban noise as he aurally hunts familiar cues and patterns of the environment that he relies on for safe travel.

- The young boy with cerebral palsy who uses a frame for support: as well as his mobility being challenged, he has a pronounced startle reflex which causes him to jump at loud sounds. The is doubly difficult, as due to his immobility, he cannot easily move from the source of the "noise".

- The middle aged man with hyperacusis who lives in a social housing apartment finds the incessant environmental noise ingress from his neighbours and the adjacent street intolerable. The council does not sympathise and his GP, unacquainted with the condition, classes him a hypochondriac.

- The older woman who has spent her life as a carer for her psychotic son who also suffers from hyperacusis. She has learnt to habitually monitor the environment for loudness on his behalf, and has over-sensitised herself in the process, becoming more and more intolerant to everyday sound.

- The musician who suffers from a mix of noise-induced hearing loss, tinnitus, hyperacusis and vertigo. He cannot tolerate music and music making anymore. Not only does he suffer the loss of his passion, the continuous tinnitus in both ears is making him borderline suicidal. The doctor tells him there is no cure, and this intensifies the negative feelings and loudness of the tinnitus.

- The young woman with misophonia who is obliged to eat alone, due to her strong negative emotions triggered by the eating sounds of others. A fellow passenger innocently opens a packet of crisps on a bus and she is filled with incontrollable anger.

- The incessant bleeps of the neonatal intensive care unit, where the premature baby's hearing is low down the list of existential priorities.

These are just a few scenarios that I have learnt on the back of my studies into hand dryer noise, which drew considerable attention in the media and prompted people to contact me directly with dilemmas coping with everyday noise.

3. Hand Dryer Noise

Back in July 2013, I was vexed by the Daily Mail's spin on my research (which formed the bulk of my IOA Diploma project in 2012) when they announced: "Super fast hand dryers may be loud enough to damage people's hearing". This was certainly not a conclusion from my research – following *The Control of Noise at Work Regulations 2005*, to risk permanent hearing damage one would need daily noise exposure over an extended period of time. Frustratingly, this caption obfuscated the subtler message of product sound design I was keen to impart: pain, fear, discomfort, anxiety, sensory shutdown, social exclusion and the onset of phobia that was coming about due to the quality and level of sound generated by high-speed hand dryers within the highly reflective acoustic of the WC.

What the users whom I was hearing about have in common is what we could categorise as sensitive hearing, a condition that the standard A-weighted decibel used in most acoustic standards does not account for, leaving them vulnerable. As a somewhat "normal" adult male hearer with minor unilateral tinnitus, I had found the new generation of hand dryers intrusive, rude even, but was drawn to the issue of sensitive hearing when I become a father. It was in 2007 I was shocked by a nappy changing facility in an amusement park in Hong Kong, which was on the same height on a wall in between a line of four Panasonic Denko's Quick Power Dry FJ-T13V1-W hand dryers. There were in constant use, and my adult hearing perception of the loudness was that it was akin to being close up to a jet aircraft taking off. My infant, naturally, was highly distressed, and as a result the facility in my opinion was evidently not fit for purpose.

High-speed hand dryers have been an engineering success story, chiming with the prevailing agenda of austerity and sustainability; but what is the trade off? Well, the rule of thumb is, the faster the hand drying cycle the louder the sound! And the notion of ‘noise as power’ is a feature that has been actively marketed. Just look at the product names: Airblade, Airforce, Air Fury, G-Force, Hurricane, Rafale, Jet Towel, Tornado, Typhoon. These names are rife with muscularity, anger, violence, extreme weather and militarisation and, to be fair, there are many people with sensory seeking behaviour who relish the visceral aural and tactile power related to high-speed hand drying.

Beyond my own family, I have been informed by many parents that their children were terrified by the sound of high-speed hand dryers; and, as all caring parents of young children will know, the last thing you want to instil is a linkage between discomfort and toilets. Toilets offer an unusually quiet zone within the urban setting with levels as low as 45 dB LAeq; so the accidental triggering of a high-speed hand dryer (which is easily done by some brands in cramped conditions), marking an immediate shift in the room’s sound pressure to easily 80 to 95dB LAeq, will quite naturally elicit a flight-or-fright response in, not only kids, but, I would say, the majority of users.

It is well-documented that children’s hearing is much more acute than adults’, particularly at the higher region of the audible spectrum (as exploited by the Mosquito Anti-loitering Device and rodent and bird prevention devices). Apart from cognitive abilities, there are some basic physiological differences such as the size of the auditory canal, which, for infants and children, resonate at much high frequencies than for adults. The high-speed dryer also generates a lot of high-frequency sound due to massive air turbulence; thus the problem for kids is compounded. Moreover, it is a major challenge to vocally reassure your child due to the compromising impact on speech intelligibility.

It is not just infants and children who have sensitive hearing. I found particular complaints among the following groups: visual impairment, hearing aid users, Alzheimer's disease, Ménière's disease, cerebral palsy; and, most significantly, hyperacusis sufferers, and hyperacute hearing in autism and Asperger syndrome.

Here is a typical comment from someone with hyperacute hearing:

> “I can't stand those hand dryers and it amazes me whenever I see people nonchalantly using them like the sound is nothing. It's very painful for me. I won't go in restrooms that have them unless it's absolutely necessary and if someone uses the dryer while I'm in there, I plug my ears. I don't care if I look like an idiot.” (Drever 2013)

There are encouraging technological developments with a new range of dryers consciously designed for quieter operating levels, such as Jet Towel Dryer JT-SB216JSH and Airdri Classic+ MkII; however, the challenge of reducing sound is not solely for the product maker, but for the planner, the architect and, most importantly building acoustician. WCs can be very small (e.g. $20m^3$) and are often rectangular, surrounded by surfaces with very low absorption coefficients across the spectrum, resulting in an ultra-reflective space with high frequency room modes. They are the most problematic space, acoustically speaking, in which to install a high speed hand dryer.

From a review of marketing material and communications, it is apparent that the information from product makers on sound levels is in general unclear. It is seldom explicit if they are referring to sound power or sound pressure, and there is a common misunderstanding that the operating sound level in dB or dB(A) that is stated on the product spec is the level that one would actually experience in situ.

It is evident, even from this initial study, that there is a major issue when considering the impact on vulnerable sub-groups, which in the most extreme case could result in people being excluded from public space, the workplace and education. This is not a call for silent loos, as shared toilet provision requires a certain level of background noise for acoustic privacy, without which can impact on other common health issues such as paruresis and parcopresis. (For more details on the hand dryer study see Drever 2013)

4. Vulnerable Groups

The issues presented above are common knowledge, not just from our professional lives, but from our day to day behaviour, family life and community activities. And if you are already 40 years old, (and have escaped other forms of hearing impairment uni- or bilateral lateral) you will probably be beginning to notice the onset of presbycusis, affecting your speech intelligibility skills, especially in noisy environments (curtailing the cocktail party effect). Our sense of hearing is a superbly impressive, yet highly complex, variable and precarious systems – many things can go awry, and it links to our sense of self and well-being, fright and terror (thinking of the fight-or-flight response hormones, corticotropin releasing hormone and adrenocorticotropic hormone) not forgetting that the ear is a very real source of acute pain (nociceptors).

The key themes in fact are already spelt out in the WHO's *Guidelines for Community Noise* (1999), stating, "protective standards are essentially derived from observations on the health effects of noise on 'normal' or 'average' populations. […] are usually adults […] are selected because of their easy availability. However, vulnerable groups of people are typically underrepresented." (WHO 1999:53)

In the rapidly evolving field of sound studies, the same agenda is at play. "Sound studies has a creeping normalism to it that is, an epistemological and political bias towards an idealized, normal, nondisabled hearing subject." (Sterne in Novak & Sakakeeny 2015:73)

The normal equal-loudness-level contour is an exemplar of the normative even idealized hearing subject. For the test, it requires what it calls "otologically normal person". That is a "person in a normal state of health who is free from all signs or symptoms of ear disease and from obstructing wax in the ear canals, and who has no history of undue exposure to noise, exposure to potentially ototoxic drugs or familial hearing loss" (BS ISO 226:2003). On top of that is stipulates an age range, 18–25 years. This demographic and profile is the strongest and healthiest stage in human life.

I have added to and amended the list of vulnerable subgroups presented in the excellent WHO *Guidelines for Community Noise* (1999) documents, showing, in a non-exhaustive or prescriptive manner, the contexts, conditions and/or stages of life that are of particular vulnerability:

- people dealing with complex cognitive tasks
- people who rely on effective speech intelligibility
- sleep disturbance (shift workers)
- antenatal, neonatal (premature babies), infancy and childhood
- over-60s/ older people
- effects from ototoxic medications
- visual impairment
- hearing impairment (conductive, sensorineural & mixed hearing loss)
- other hearing disorders: hyperacusis, misophonia, phonophobia, recruitment

– hearing aid users and cochlear implants
– vestibular conditions such as superior semicircular canal dehiscence, Ménière’s disease, labyrinthitis
– autistic spectrum disorders with hyper/hypo-acute hearing
– dementia and Alzheimer’s disease
– hypertension
– chronic fatigue syndrome
– acoustically-related social phobias (i.e. parcopresis, paruresis)
– post-traumatic stress disorder (i.e. exaggerated acoustic startle reflex)
– migraine headaches
– epilepsy
– Lyme disease
– cerebral palsy
– Tourette's syndrome

5. Conclusion: Auraldiversity

In contrast to the medicalized term “otologically normal”, I have provocatively coined the term auraltypical which I use to refer to a “normal” hearer (of which I was one until recently I developed moderate tinnitus in my right ear), a term that I have adapted from the autistic community, which often label people who are not on the autism spectrum as neurotypical. Neurotypical refers to non-autistic people’s normality and implies their tendency to impose their understanding of normality on everyone else as correct and natural.

Accompanying auraltypical hearing which we are trained to practice as acousticians, is the actual variety of (often less than ideal) hearing that we experience throughout a normal day and throughout our lives albeit to varying degrees (from the trifling experience of a temporary threshold shift or transient ear noise to intolerable pain from hyperacusis) which can be called auraldiversity.

This is an exciting time for acoustics, and there is a much innovative and challenging research being undertaken right now, such as the EARS project and the development of the ISO Standard on Soundscapes. Getting beyond the “gold standard” of equal loudness contours, adopting a more auraldiverse and auralinclusive approach, we can offer much more to the wellbeing of a heterogeneous and ageing population.

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