

Disability rights aspects of ambient noise for people with auditory disorders

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ABSTRACT

The United Kingdom (UK), United States (US) and European Union (EU) guarantee people with disabilities certain rights, with goals of full enjoyment, active inclusion, and equal participation in society. This approach is also found in the United Nations Convention on the Rights of Persons with Disabilities, adopted by the EU in 2008.

Ambient noise is a disability rights issue for individuals with hearing loss. Many cannot understand speech in noisy places, with or without hearing aids. Noise worsens symptoms for those with tinnitus and hyperacusis.

Noisy restaurants, stores, and other places deny full enjoyment and equal participation in public life to those with hearing loss, tinnitus, and hyperacusis. Legislative and regulatory action is needed to provide quiet environments, with established noise standards vigorously enforced. Technologies and environmental modifications to control noise are well known, readily available, and relative inexpensive. The simplest modification is merely turning down the volume of amplified sound.

Reduced ambient noise levels facilitate communication for everyone and prevent hearing loss, tinnitus, and hyperacusis in those without auditory disorders.

INTRODUCTION

Impairment is a physical difference from normal but disability is a social construct, “the disadvantage or restriction of activity caused by a contemporary social organization which excludes people with physical impairments from participation in the mainstream of social activities”. [1] A good example of the difference between impairment and disability would be a town where there are so many deaf people that everyone learns sign language. The deaf people are clearly impaired, but they are not disabled in that environment. When they travel to a nearby town where people haven't learned sign language, they are disabled.

The word *disability*, meaning a physical or mental impairment that limits a person's movements, senses, or activities, is commonly used, including in law. Historically, disabled people were marginalized in society. If persons with disabilities survived childhood they were

generally isolated and neither expected nor allowed to participate fully in public life. [1,2] For those with impaired mobility, streets, government offices, restaurants, retail stores, and public transportation were largely inaccessible. For those with blindness or deafness, special homes and schools funded by governments or charities provided care but isolated them from families and from public life. [3,4] Those with mental illness were warehoused in asylums. [5] In a shameful chapter of history, Nazi Germany sterilized mentally and physically disabled persons living in institutions, and then began killing them. [6]

The disability rights movement began in the nineteenth century and reached maturity in the last part of the twentieth century. [7] The current theoretical framework for disability rights is clear: Persons with disabilities have the same fundamental rights in society as those without disabilities, and the goals both for persons with disabilities and societies in which they live are the full enjoyment of life, with active inclusion and equal participation.

The United Kingdom (UK) was the first country in the world to pass a law granting rights to disabled persons. Disability laws there have evolved from the Chronically Sick and Disabled Persons Act (1970) [8] to the current Equality Act (2010). [9] Under the Equality Act (2010), one is considered disabled if one has “a physical or mental impairment that has a substantial and long-term negative effect on the ability to do normal daily activities”. Legal protection is broad, protecting those with disabilities against discrimination at work, in education, as a consumer, when using public services, or when buying or renting property.

In the US, the Americans with Disabilities Act (ADA) became law in 1990, [10] and was revised in 2008. [11] ADA prohibits discrimination against individuals with disabilities in all areas of public life, including jobs, schools, transportation, and all public and private places that are open to the general public. Under ADA, someone with a disability is “a person who has a physical or mental impairment that substantially limits one or more major life activities.” ADA further defines major life activities as including, but not being limited to, “caring for oneself, performing manual tasks, seeing, **hearing** [emphasis added], eating, sleeping, walking, standing, lifting bending, breathing, learning, reading, concentrating, thinking, communicating, and working.” Furthermore, the ADA standard is that “no individual shall be discriminated against on the basis of disability in the full and equal enjoyment of the goods, services, facilities, privileges, advantages, or accommodations of any place of public accommodation.” The “full enjoyment” standard has been upheld by the Appeals Court, but has not yet been litigated at the US Supreme Court.

The United Nations (UN) Convention on the Rights of Persons with Disabilities (UNCRPD) was ratified in 2008. [12] The Convention states:

“The purpose of the present Convention is to promote, protect and ensure the full and equal enjoyment of all human rights and fundamental freedoms by all persons with disabilities, and to promote respect for their inherent dignity.

Persons with disabilities include those who have long-term physical, mental, intellectual or sensory impairments [emphasis added] which in interaction with various barriers may hinder their full and effective participation in society on an equal basis with others.”

The EU is a party to UNCRPD and promotes the active inclusion and full participation of disabled people in society, in line with the EU human rights approach to disability issues. [13] Disability is a rights issue and not a matter of discretion. The European Union sets goals, guidelines, and standards, but passage, implementation, and enforcement of laws and regulations are left to each member country. The objectives of the European Disability Strategy 2010-2020 include accessibility, participation, equality, employment, and social

protection. [14] The goals are laudable, but an analysis of implementation in 2017 found that much work remains to be done. [15]

The European Federation for the Hard of Hearing is a European non-profit non-governmental organization. Its accessibility goals are subtitling of television programs and movies, speech to text devices in public places, text over internet protocol, hearing loops, and access to emergency telephone lines by the deaf and hard of hearing. Mention is made of the need for good acoustics so the deaf and hard of hearing can understand speech, but just in general terms. [16]

The European Union of the Deaf (EUD) is comprised of national associations of deaf people from 28 EU member countries and other countries. The EUD has no statutory authority but coordinates activities for the deaf at the EU, and has written policy papers on sign language, cochlear implants, education, and communications in elevators. Its main objectives are recognition of the right to use an indigenous sign language, empowerment through communication and information, and equality in education and employment. [17]

Summary of legal frameworks for disability rights

The basic approach in the UK, US, UNCRPD, and EU is broadly the same: people with disabilities have the same rights in society as people without disabilities, and governments and private businesses have an obligation to make changes needed to allow persons with disabilities the full enjoyment of places available to the public. These changes are called *reasonable adjustments* (UK) or *reasonable accommodations* (US). For those with hearing impairment, these rights appear to be most fully implemented for the totally deaf or significantly hearing impaired, especially in the workplace. Those with lesser auditory impairments appear to be included generally, but have no specific statutory protection. Neither UK nor US has established standards for ambient noise in public places. Legal protection under disability laws for those with partial hearing loss, tinnitus, and hyperacusis may need to be sought through litigation.

SCOPE OF THE PROBLEM

Why is ambient noise so important? There are three main reasons. First, because so many people are affected. Studies of auditory disorder prevalence are based on surveys with extrapolations to population estimates, so there may be questions about the accuracy of the statistics. There is no single definition for significant hearing loss but this usually means at least a 25-decibel decrement in both ears. [18] Estimates for tinnitus and hyperacusis prevalence are problematic because there are no objective measures for these disorders. Some reports divide symptoms into mild, moderate, and severe, based on patient reports. Reasonable consensus estimates are that approximately 15% of adult populations in the US, UK, and EU have significant hearing loss, 7-10% have bothersome tinnitus, and 2-5% have bothersome hyperacusis.

Table 1: Prevalence of auditory disorders in adults

Condition	US	UK	EU
Hearing loss	48 MM (15%) [18]	11 MM (16%) [19]	55 MM (15%) [20]
Tinnitus	32 MM (10%) [21]	6.5 MM (10%) [19]	70 MM (13.7%) [22]
Hyperacusis	19MM (5.9%) [23]	1.3 MM (2%) [24]	No data available

Second, significant hearing loss most commonly affects older people. [20,22] Estimates vary, depending on the age ranges used, but in the US approximately 25% of people age 60-69, 50% of people age 70-79, and almost 80% of those over age 80 have significant hearing loss. [18] Older age cohorts are rapidly growing [25,26] as infectious disease is controlled, medical care advances and becomes more available, and hygiene and nutrition improve.

The EU Charter of Human Rights “recognises and respects the rights of the elderly to lead a life of dignity and independence and to participate in social and cultural life.” [27] Older people are a vulnerable population recognized by many countries as needing special protection. Older people tend to have medical comorbidities, cognitive impairment, and difficulties in performing activities of daily living. Many are poor and live alone. Hearing loss exacerbates these vulnerabilities, worsening social isolation [28] and being correlated with depression, [29] dementia, [30] falls, [31] and death. [32] Hearing aids are only a partial solution for hearing loss. Health insurance coverage for hearing aids is limited in the US, and coverage under national health programs in other countries may require meeting strict criteria. Many people with hearing loss do not get hearing aids for reasons of ignorance or stigma. [33] Hearing aids may provide only limited assistance in understanding speech, especially in noisy environments. Perhaps because of this, up to 40% of those who have obtained hearing aids do not use them. [34].

Third, ambient noise levels appear to be increasing. In restaurants and bars, high noise levels create an aura of excitement, attract younger patrons, and increase food and beverage sales. In some retail stores, high noise levels attract younger customers while repelling some older ones. Noise levels once limited to rock concerts are now a common feature of everyday life. [35]

Higher noise levels may be due to widespread misunderstanding of safe noise exposure levels. The US National Institute for Deafness and Other Communication Disorders implies that the 85-decibel US occupational noise exposure standard [36] is safe for the public, stating, “Long or repeated exposure to sound at or above 85 decibels can cause hearing loss.” [37] No time exposure limit is given. The World Health Organization also uses the 85-decibel (dB) US occupational noise exposure level with an 8-hour daily time limit. [38] (The occupational standard is A-weighted, 85 dBA, to reflect the frequencies of human speech. Most organizations do not mention weighting.) An occupational noise exposure level is not a safe noise level for the public. [39] Due to the logarithmic nature of the decibel scale, 85-dB sound has 31.6 times more energy than 70-dB sound. The only evidence-based safe noise exposure level to prevent hearing loss is a time-weighted average of 70 dB for 24 hours ($L_{eq24}=70$). [40] Actual safe noise exposure levels to prevent hearing loss may be even lower, because studies of noise-induced hearing loss are based on 40 year occupational exposure but life expectancy in the developed world is now approaching 80 years. Additional exposure time may account for the very high prevalence of hearing loss reported in older age groups.

[18]

Two other phenomena deserve mention. First, if people are present, high ambient noise levels generate further increases in ambient noise. A positive feedback loop, called the Lombard effect, or “noise-dependent regulation of vocal amplitude,” is created. [41] If the ambient noise in a space is too loud for normal conversation, people speak more loudly so they can be heard. When everyone in the room does this, the ambient noise level in the space increases, so people have to speak even more loudly. Eventually, everyone is shouting into each other’s ears, but people still can’t carry on a conversation.

The second phenomenon is that many adults, especially older adults, can hear sound but cannot understand speech. [42] Audiometry testing shows only minimal hearing loss, but tests of speech comprehension are abnormal. This is most likely the result of what is now called hidden hearing loss, a recently reported synaptopathy caused by noise damage to nerves in the cochlea, rather than damage to the cochlear hair cells. [43] The inability to follow one conversation among many in a noisy room may not meet the statutory definitions of disability, but it clearly is a problem for many older people.

IMPLICATIONS OF AMBIENT NOISE FOR PERSONS WITH PARTIAL HEARING LOSS

The primary complaint of patients with sensorineural hearing loss is difficulty understanding speech in noisy environments. This is a problem for those with normal hearing, too. The ability to understand speech indoors when conversing at 1 meter distance is 100% at 70 dBA ambient noise, but decreases to zero at only 75 dBA ambient noise levels. [Figure D-1 in 39]. Those with moderate hearing loss can’t understand speech in a restaurant with ambient noise levels above 58 dBA. [44] Reverberation is also an important consideration for acoustic design. Less reverberant rooms make it easier to understand speech, with the ideal reverberation times being 0.20-0.50 seconds. [44]

For older people, there are three main hypotheses explaining the difficulty understanding speech in noisy environments: the peripheral, the central-auditory, and the cognitive hypotheses. [45] All three may be involved. The basic concept needed to understand the implications of ambient noise for persons with partial hearing loss is the signal-to-noise ratio, also called the speech-to-noise ratio. [46] How loud is speech compared to background noise, especially in indoor spaces? In general, hearing-impaired listeners need a higher signal-to-noise ratio than those with normal hearing to achieve the same amount of speech intelligibility. [47] Looked at another way, the thresholds for speech intelligibility in those with hearing impairment are generally higher than for those with normal hearing.

Typical complaints of hearing aid users include “everything is too loud”, “I can hear sound but I can’t understand speech”, and “I can hear, but I just can’t understand all the words.” Hearing aids do not provide an auditory correction for hearing loss the way lenses provide a visual correction for common visual problems [48], especially in noisy environments. Sensorineural hearing loss involves damage to the basic sense organ for hearing, the hair cells in the Organ of Corti. A pure conductive hearing loss could be treated effectively by amplification. Sensorineural hearing loss is analogous to a retinal problem, e.g., macular degeneration or diabetic retinopathy, where the basic sensory cell is damaged or destroyed. The world’s best lens won’t help much.

Hearing aid manufacturers have responded with a variety of technological advances, including enhancing the signal-to-noise ratio, broadening the bandwidth, using binaural rather than unilateral hearing aids, complete-in-the- canal hearing aids which use the pinna’s spectral shaping of sound, low distortion or higher fidelity, directionality, multiple microphones, active noise cancellation, and speech processing algorithms. [49] In studies conducted by or for

hearing aid manufacturers, newer digital hearing aids are better than older models, but none of these approaches is entirely successful.

IMPLICATIONS OF AMBIENT NOISE FOR PERSONS WITH TINNITUS

Tinnitus is a poorly understood phenomenon of ringing in the ears [50,51]. The exact cause of tinnitus is still unknown, but noise exposure- either chronic noise exposure or a one-time exposure, especially impulsive noise- can cause lifelong symptoms. The type of noise varies from person to person. Some report a clicking, some report a buzzing, and some report almost pure tones.

For many tinnitus sufferers, the tinnitus sound is most noticeable or sometimes only noticeable when it is quiet. This observation forms the basis of perhaps the only proven form of treatment for tinnitus, masking therapy. Either sound generators or hearing aids with a masking feature provide a low-level sound that masks the patient's own tinnitus. For most people with tinnitus, loud noise exposure makes their symptoms worse. [52]

IMPLICATIONS OF AMBIENT NOISE FOR PERSONS WITH HYPERACUSIS

Hyperacusis is by definition sensitivity to noise. The most common etiology of hyperacusis is noise exposure, as with tinnitus either chronic or one-time impulsive noise exposure. While some people with hyperacusis have relatively mild symptoms, others are severely impaired and must live their lives in relative isolation because the world is painfully noisy for them. [53]

For decades it was thought that hyperacusis was psychosomatic, because there were no pain fibers in the auditory nervous system, but recent research has found Type II pain fibers in the auditory nerve. [54] Those with hyperacusis often describe the pain as "a needle in the ear" or "a hot poker to the eardrum." Many wear earplugs, sometimes supplemented by earmuff hearing protection in loud everyday environments. In loud urban areas such as New York City, the most severely affected wear hearing protection inside their homes or apartments with windows closed and heavy drapes drawn to keep noise to a minimum. Those with milder symptoms are able to leave their homes to shop for food but often cannot work, or go to restaurants, movies, loud retail stores, or sports events.

DISCUSSION AND CONCLUSIONS

Partial hearing loss can be treated with hearing aids but these do not restore normal hearing, especially in noisy environments. The only proven treatment for tinnitus is noise masking, and for hyperacusis noise avoidance. There is significant overlap among partial hearing loss, tinnitus, and hyperacusis, [55] and many of those affected suffer from two or all three of these auditory conditions.

High ambient noise levels make it difficult if not impossible for those with partial hearing loss to understand speech, generally worsen symptoms for those with tinnitus, and cause pain for those with hyperacusis. High ambient noise levels turn impairments into disabilities, making it impossible for those with auditory disorders to fully enjoy public places that other people enjoy. This is especially true for restaurants, so vital to social life. They are clearly disabled within the definitions of the UK Equality Act (2010), the US ADA, the EU's European Disability Strategy, and the UNCRPD.

The solution for those with partial hearing loss is not to provide them with more advanced digital hearing aids, with features like directionality and advanced processing protocols. These won't help persons with tinnitus or hyperacusis anyway. The only effective solution is a *reasonable adjustment* (UK) or *reasonable accommodation* (US): reduce ambient noise levels in public spaces, especially indoors. This would appear to be required under disability laws in the UK and US, and implied by EU and UN disability guidelines.

Reducing ambient noise levels in public places will require government action. In the EU, there is great concern about health impacts of environmental noise but little apparent concern for indoor noise. One million healthy life years are lost annually from traffic-related noise in the western part of Europe [56] but 3.9 million healthy life years are lost annually from hearing loss. (Table 14 in [57])

Government recommendations and standards for indoor sound levels, embodied in laws and regulations, are needed to protect those with auditory disabilities.

Laws could specify decibel and intelligibility levels, with average and peak sound limits and reverberation times. Existing standards for classroom acoustics [58] could be adapted for restaurants, retail stores, and malls. Alternatively, laws could specify a functional measure, i.e., indoor sound levels low enough to allow persons "to converse without straining to speak or to be heard." [59] This is approximately 70-75 dBA [40]. To meet the needs of those with hearing loss, a 60 dBA standard may be needed, with a reverberation time of 0.2-0.5 seconds. [44]

Enforcement is potentially easy with crowd-sourced measurement and reporting. Accurate smart phone sound meter apps can record sound levels and document the time and location of the recording. [59] With appropriate enabling legislation, recordings made by restaurant or retail patrons using these apps can provide data for municipalities to initiate enforcement action against noisy establishments.

The technologies for reducing and controlling noise have been known for at least half a century [61]: design mechanical devices to be quieter through engineering specifications and material choices, or isolate, insulate, reflect, deflect, or absorb the sound. For the built environment, noise control techniques are also well known and can be used in both new construction and remodeled spaces. [62] If a major remodel is not contemplated, there are relatively inexpensive retrofitting solutions- from ceiling panels, wall hangings, carpets, drapery, and others- that can help control noise and reduce reverberation. The simplest environmental modification costs nothing: turn down the volume of any amplified sound.

Treatment of hearing loss is currently limited to hearing aids, with cochlear implants reserved for the severely hearing impaired. While research continues to regrow cochlear hair cells, to prevent auditory damage after noise, and to find treatments for tinnitus and hyperacusis, policy efforts focus on making better hearing aids and personal sound amplification products available more cheaply to older people. This was the major recommendation of two recent US federal studies [63,64] with no mention of prevention or environmental modification.

Discussing better hearing aids today without mentioning the need for lower ambient noise levels is like discussing better wheelchairs, crutches, and braces in the 1960s for those affected by polio without mentioning the need for environmental modifications. Even after vaccines led to the eradication of polio in the US, those affected by polio, and others with impaired mobility, did not obtain full independence until architectural modifications required by the ADA were implemented. Relatively simple design changes, e.g., lever-style door handles, lower light switches, wheelchair ramps, curb cuts, wider corridors, handrails, and accessible toilet compartments, allowed independent mobility for persons with physical disabilities.

Environmental modifications meant to help the disabled actually help everyone. Children can reach lower light switches. Wider corridors allow people to pass each other more easily. Wheelchair ramps or curb cuts help parents pushing a baby in a stroller, or delivery and repair workers with wheeled equipment. Flat entryways with doors that open automatically when someone approaches are even better, making entry easy for all. Similarly, lower ambient indoor noise levels will help everyone: parents speaking with their toddler, grandparents trying to follow the conversation at a family dinner in a restaurant, friends updating each other about what is going on in their lives without sharing their news with the world, or young lovers whispering sweet nothings to each other.

Those with auditory disabilities don't need special treatment. They need a universal design environment, free of auditory barriers, to participate fully and equally in life. [65] Reducing ambient noise benefits all, and helps prevent future hearing loss, tinnitus, and hyperacusis in those without auditory disorders.

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Auditory processing disorder is an inability to process, interpret, and retain what is heard and is often mistaken for ADHD. Find signs and symptoms here. The National Center for Learning Disabilities lists four types of auditory skills needed for a child to properly process what he or she hears: 1. Auditory discrimination is the ability to notice, compare, and distinguish the distinct and separate sounds in words. If a child has difficulty with auditory discrimination, he or she may confuse similar words like seventy and seventeen, have trouble learning to read, and be unable to follow directions even when the child appears to be paying attention. 2. Auditory figure-ground discrimination is the ability to pick out important sounds from a noisy background. Auditory processing disorder (APD) is a hearing problem that affects about 5% of school-aged children. Kids with this condition, also known as central auditory processing disorder (CAPD), can't process what they hear in the same way other kids do. This is because their ears and brain don't fully coordinate. With the right therapy, kids with APD can be successful in school and life. Early diagnosis is important. These kinds of problems usually happen when there is background noise, which is often the case in social situations. So kids with APD can have trouble understanding what is being said to them when they're in noisy places like a playground, sports events, the school cafeteria, and parties. What Are the Signs & Symptoms of Auditory Processing Disorder? His paper on the disability-rights aspects of ambient noise was presented at a recent meeting of the Acoustical Society of America. I can guarantee that people with hearing impairments don't fully enjoy noisy restaurants, he said. Restaurants these days are louder than ever, to the point where critics (led by The Post's Tom Sietsema) check volume levels and diners grouse about them. AD. Auditory disorders are invisible disabilities. The problems associated with hearing loss are underestimated. AD. The din is also potentially injurious to diners with hearing disorders such as tinnitus (ringing in the ears) and hyperacusis (noise-induced pain). Sometimes, their symptoms don't intensify until a day or so after exposure, much like a sunburn. Additionally, auditory processing has been found to be a significant deficit in children with developmental reading disorders. Therefore, training the auditory processing components for children has potential to improve reading ability. The current study aims to identify if using the forbrain device during reading instruction increases students' reading ability. Subjects. A total of N=32 participants will be enrolled. They will be healthy university students (age range 18-35 years; male or female) with no history of neurological or psychiatric disorders and normal hearing (hearing level will be determined through standard audiometry). Music expertise will be disregarded, as it has been shown to enhance the encoding of speech sound features and auditory discrimination.