Disability rights aspects of ambient noise for people with auditory disorders under the Americans with Disabilities Act

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People with auditory disorders have sensory impairments that meet the legal standard of having disabilities. Individuals with hearing loss cannot understand speech in noisy places, with or without hearing aids, and noise worsens symptoms for those with tinnitus and hyperacusis. People with auditory disorders need quiet conditions. High ambient noise levels pose an access barrier for them, turning their disorders into disabilities and denying them full enjoyment of restaurants, stores, and other places. The Americans with Disabilities Act guarantees people with disabilities full enjoyment of places of public accommodation. Legislation and regulations are needed to establish ambient noise standards that then must be enforced. Enforcement by crowd-sourced noise measurements using smart phone sound level meter apps is feasible. Technologies and environmental modifications to control noise are well known, readily available, and relatively inexpensive. The simplest modification is turning down the volume of amplified sound, which costs nothing. Lower ambient noise levels facilitate communication for everyone and prevent hearing loss, tinnitus, and hyperacusis in those without auditory disorders.
INTRODUCTION

As defined in the Americans with Disabilities Act (ADA), a disability is a physical or mental impairment that substantially limits one or more major life activities. [1] Historically, disabled people were marginalized in society. If persons with disabilities survived childhood, they were usually isolated and neither expected nor allowed to participate fully in public life. [2,3] For those with impaired mobility, streets, offices, restaurants, stores, and public transportation were largely inaccessible. For the blind and the deaf, special homes and schools funded by governments or charities provided care but separated them from families and isolated them from public life. [4,5] Those with mental illness were warehoused in asylums. [6] In shameful chapters of history, 60,000 institutionalized disabled Americans were sterilized involuntarily [7] and in Nazi Germany institutionalized disabled persons were first sterilized and later killed. [8]

The disability rights movement began in the nineteenth century and reached maturity in the last part of the twentieth century. [9] 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 the societies in which they live are the full enjoyment of life, with active inclusion and equal participation.

HEARING LOSS AFFECTS 48-60 MILLION (21-25%) U.S. ADULTS

Hearing loss is an impairment that limits the major life activities of hearing and communicating, both specifically mentioned in the ADA. [1] Hearing loss is the best understood of the auditory disabilities and the only one readily treated. It is easily measured, animal models have been extensively studied, the dose-response relationship between noise exposure and hearing loss is clearly defined, and the biological basis of noise-induced hearing loss is well understood. [10] Hearing aids are used to treat hearing loss, with cochlear implants reserved for the severely hearing impaired.

The problems associated with hearing loss are underestimated for several reasons. First, auditory disorders, including hearing loss, have no visible stigmata. Second, people with hearing loss compensate for it, e.g. by asking someone to repeat a word or by cupping a hand to the ear to amplify sound. Third, hearing loss, defined by the World Health Organization as greater than 25-decibel (dB) hearing loss [11], does not become common until old age. In the United States (U.S) approximately 25% of people age 60-69, 50% of people age 70-79, and almost 80% of those over age 80 have bilateral hearing loss. [12] Of note, significant hearing loss with age (>10 dB) is noise-induced hearing loss, and not normal physiological aging. (Figure 23 in [13]) Older people are largely invisible in American society [14], being out of the workplace and often living alone (Table 5-3 in [15]) and far from family. Hearing loss in retirees has no
direct economic impact. Medicare rarely covers hearing aids and has only limited coverage for other hearing health care, so hearing loss has little direct impact on health insurance costs. Fourth, hearing loss is not viewed as a serious disorder because it is commonly believed that "no one dies from hearing loss."

Unfortunately, hearing loss is not a benign condition. In younger people, it is associated with significant social and economic difficulties. [16]. In older people, hearing loss is correlated with social isolation [17], which in turn is associated with increased mortality. Hearing loss in older people is also correlated with increased rates of falls [18], depression [19], and dementia [20], each of which is associated with increased medical care, increased medical costs, and mortality. Hearing loss has also been shown to be an independent factor for mortality. [21]

The main complaint of people with hearing loss is difficulty understanding speech in noisy environments. Even for those with normal hearing, the ability to understand speech indoors when conversing at 1 meter decreases from 100% at 55 A-weighted decibels (dBA) ambient noise to 50% at 70 dBA and zero at only 75 dBA. (Figure D-1 in [22]) Those with hearing loss can't understand speech if ambient noise levels exceed 58 dBA, especially in reverberant spaces. [23]

To understand speech, listeners need a 3 dB difference between background or ambient noise and speech. In general, hearing impaired listeners have a higher threshold for understanding speech and need a higher speech to noise ratio or signal to noise ratio than those with normal hearing to achieve the same amount of speech intelligibility. This can be up to a 7-15 dB difference for those with severe impairment. [24,25].

Hearing aids help less than desired in understanding speech, especially in noisy environments and at greater distances. [26] 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." Analog hearing aids amplify all sounds, so the signal to noise ratio stays approximately the same. Also, much hearing loss is in the higher frequencies. [27] High frequency hearing loss worsens speech comprehension [28] because consonant sounds, needed to differentiate among similar sounding words, are high frequency sounds. The basic sensory organ for hearing, the Organ of Corti in the cochlea, contains hair cells on a membrane that vibrates at different locations for each frequency. Noise damages cochlear hair cells. [10] Delivering amplified high frequency sound waves to damaged hair cells that can't perceive them doesn't help the user understand speech. Hearing aids thus do not provide an auditory correction for hearing loss the way lenses provide a visual correction for common visual problems [29].

Hearing aid manufacturers have introduced a variety of technological advances, including enhanced signal-to-noise ratio, broadened bandwidth, complete-in-the-canal hearing aids that use the pinna's spectral shaping of sound, low distortion.
Another cause of difficulty understanding speech in noise may be hidden hearing loss. This is the result of noise damage to the synapses between the cochlear hair cells and cochlear nerve terminals, i.e., a synaptopathy. [32] Audiometry testing shows only minimal hearing loss, but tests of speech comprehension are abnormal. The inability to follow one conversation among many in a noisy room is a problem for many older people even with preserved auditory sensitivity. [33]

TINNITUS AFFECTS 35-48 MILLION (11-15%) AMERICAN ADULTS

Tinnitus is ringing in the ears, or more specifically the perception of sound for which there is no external source. [34,35,36] Tinnitus is less well understood than hearing loss. The most common cause of tinnitus is chronic noise exposure, but one-time noise exposure can cause lifelong symptoms. Diagnosis of tinnitus is by subjective report. The type of tinnitus noise reported varies from person to person, ranging from clicking to buzzing to almost pure tones. Researchers think tinnitus comes from hyperactivity within the central auditory system resulting in the perception of sound in the absence of an outside sound source. There is no cure for tinnitus. Symptoms range from mild to severe, sometimes being so bothersome as to lead to suicide. For many people with tinnitus, the tinnitus sound is most noticeable or sometimes only noticeable in quiet. This observation forms the basis of tinnitus sound or masking therapy. Sound generating devices, including hearing aids with built-in sound generators, are used to try to help people manage tinnitus. Other treatments include counseling or training therapies. Tinnitus treatments often do not work and are rarely covered by insurance. Most people with tinnitus avoid loud noise because it is uncomfortable and makes symptoms worse.

Approximately 50% of people with tinnitus also have hearing loss. Recent studies showed that people with tinnitus have difficulty understanding speech even without significant hearing loss. [37,38] As with hearing loss, a higher signal-to-noise ratio maybe needed for people with tinnitus to understand speech. Quiet conditions are needed to prevent discomfort and worsening of tinnitus.

HYPERACUSIS AFFECTS 19 MILLION (5.9%) AMERICAN ADULTS

Hyperacusis, discomfort from sounds that would ordinarily be acceptable to most normally hearing people, is not well understood. [39,40] For decades it was
thought that hyperacusis was psychosomatic but recent research demonstrated Type II pain fibers in the auditory nerve. [41] People with hyperacusis often describe the pain as “a needle in the ear” or “a hot poker to the eardrum.” The most common cause of hyperacusis is either chronic or one-time noise exposure. While some people with hyperacusis have relatively mild symptoms, others are severely impaired and must live their lives in isolation because ordinary everyday sounds are perceived as loud and painful.

As with tinnitus, hyperacusis is thought to be a problem within the central auditory system. Hyperacusis treatment includes sound therapy and counseling, such as cognitive behavioral therapy. These treatments rarely work. Even mild hyperacusis can cause major life disruption. Many people with hyperacusis wear earplugs when in uncontrolled noise environments, sometimes supplemented by earmuff hearing protection, which makes communication difficult. People with hyperacusis often cannot work, and cannot go to restaurants or many stores without hearing protection because the ambient noise is too loud for them. Moderate ambient noise and unanticipated noise worsen symptoms.

THE AMERICANS WITH DISABILITIES ACT

The Americans with Disabilities Act (ADA) became law in 1990 [1] and was substantially revised in 2008. [42] The ADA is a civil rights law for people with disabilities, prohibiting discrimination against individuals with disabilities in all areas of public life, including jobs, schools, transportation, and places that are open to the public. Under the ADA, someone with a disability is “a person who has a physical or mental impairment that substantially limits one or more major life activities.” The 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 [emphasis added], 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 [emphasis added] of the goods, services, facilities, privileges, advantages, or accommodations of any place of public accommodation.” The “full enjoyment” standard has been upheld at the appellate level [43], but has not yet been litigated at the U.S. Supreme Court.

ADA Title III regulations require public accommodations such as restaurants, hotels, and retail stores to be accessible to individuals with disabilities. New construction and alterations must meet federal accessibility standards, and existing public accommodations must remove barriers to allow persons with disabilities to access their goods, services, and facilities. The removal of barriers is required to the extent that it is readily achievable, i.e., easily accomplished without too much difficulty or expense. ADA Title V mandates that a federal agency, the U.S. Access Board, develop design guidelines to ensure that buildings and other facilities are accessible to individuals with disabilities. These
guidelines are developed into enforceable standards by the U.S. Department of Justice. The Department of Justice has issued architectural and communications standards to meet the needs of the deaf, but has not issued standards for ambient noise. [44]

For those with auditory disorders, ADA legal rights are most fully implemented for the deaf or significantly hearing impaired, especially in the workplace. In addition to workplace modifications to enable the deaf or severely hearing impaired to work, mandated auxiliary aids and services include but are not limited to fire alarms with strobe warning lights, communications devices, and sign language interpreters when needed. There are no ADA Access Guidelines for ambient noise in places of public accommodation.

THE AMBIENT NOISE PROBLEM

Why is ambient noise such an important issue? First, so many people have auditory disorders and therefore are impacted by high ambient noise levels. Reports on the prevalence of auditory disorders are estimates, based on extrapolation from survey studies to larger populations. Hearing loss is easily measured by pure tone audiometry. Tinnitus and hyperacusis are generally diagnosed only by patient self-report. Reasonable estimates for the U.S. are that 48-60 million adults (15%-24% of the U.S. population) have hearing loss [12,45], 35-48 million (11-15%) have tinnitus [45,46], and 19 million (5.9%) have hyperacusis. [45]

Second, ambient noise levels appear to be increasing. In restaurants and bars, high noise levels create an aura of excitement, attract younger patrons, repel unwanted older patrons, and increase food and beverage sales. High ambient noise is also found in retail stores and malls. Noise levels once limited to factories, construction sites, or rock concerts are now a common feature of everyday life. [47]

Third, high ambient noise levels disproportionately affect older Americans, about half of whom have >25 dB hearing loss bilaterally. Older people are a vulnerable population. [48] Medical illnesses and poverty are common. One-third of older people live alone [14], so restaurants are an important venue for social interaction for them. High ambient noise levels further isolate those who cannot understand speech in noisy places.

As noted above, hearing aid performance in improving speech comprehension is limited in noisy environments. Medicare doesn't cover hearing aids, which can cost $5,000-7,000 per pair, and has limited coverage for other hearing health care, so only a small percentage of older Americans who might benefit from hearing aids have them. [49,50] People delay obtaining hearing aids due to denial, cost, or perceived stigma of hearing loss [51] or don't wear them. [26,31]
WHY ARE AMBIENT NOISE LEVELS SO HIGH?

High ambient noise levels may be common due to widespread misunderstanding of the safe noise exposure level. For example, the National Institute for Deafness and Other Communication Disorders implies that 85 dB noise exposure is safe, stating, “Long or repeated exposure to sound at or above 85 decibels can cause hearing loss.” [52] The World Health Organization also uses 85 dB in its Make Listening Safe program, suggesting an 8-hour daily time limit. [53]

Eighty-five A-weighted decibels (dBA) is an occupational noise exposure standard that even with strict time limits (8 hours/day, 240 days/year, for 40 years) does not protect all exposed workers from hearing loss. [54] (The occupational standard is A-weighted to measure the frequencies perceived by the human ear. Most organizations do not mention if their standards are A-weighted. Unweighted dB measurements are usually higher than A-weighted measurements.) An occupational noise exposure level is not a safe noise level for the public because people are exposed to noise continuously (24 hours/day, 365 days/year, for a lifespan now approaching 80 years). [55] The only evidence-based safe noise exposure level to prevent hearing loss, calculated by adjusting the occupational standard for additional exposure time, is a time-weighted average of 70 dB for 24 hours. [22,56] The safe noise exposure level to prevent hearing loss may be even lower. The studies on which the occupational standard is based only used 40-year occupational exposure histories, were not adjusted for lifetime exposure, and assume noise exposure lower than 70 dB when not at work, something that is no longer true for most Americans. [57]

Despite this, the 85-decibel standard has become the de facto safe noise exposure level for the public, without any time limit. If everyone thinks that 85 decibels is a safe noise exposure level, there is no perceived problem with high ambient noise levels. (The innumeracy of the American public doesn't help. The decibel scale is a logarithmic scale. An 85-dB sound has 31.6 times more energy than 70-dB sound, not merely 21% more as might be commonly thought.) The public health danger of noise exposure for hearing is not widely recognized. In Kalamazoo County, MI, Flamme et al. found that 70% of adults found were exposed to total daily noise doses exceeding 70 dB. [57] Perhaps because of this, almost 25% of adults have noise-induced hearing loss [45], with the characteristic audiometric notch denoting noise damage. [58]

One other phenomenon deserves mention. High ambient noise levels generate further increases in ambient noise when people are present. This is called the Lombard effect or “cocktail party effect”, technically known as noise-dependent regulation of vocal amplitude. [59] When ambient noise is too loud for normal conversation, people speak more loudly to be heard, increasing the signal-to-noise ratio. When everyone in the room does this, the ambient noise level increases, so people have to speak even more loudly. Eventually, everyone is shouting into each other’s ears, but people still can’t understand what others are
trying to say. Appropriate occupant density and adequate sound absorption can help mitigate Lombard effect contributions to ambient noise.

DISCUSSION

People with hearing loss clearly meet the ADA definition of having a disability. High ambient noise levels pose an access barrier, making it difficult if not impossible for them to understand speech and to participate in conversation, especially in restaurants so important for social life. Noise generally worsens symptoms for those with tinnitus, and causes pain for those with hyperacusis. There is significant overlap among hearing loss, tinnitus, and hyperacusis, with many affected individuals having two or all three of these conditions. Whether tinnitus and hyperacusis meet the ADA disability definition or not will likely be determined in court. Even if they don’t, reducing ambient noise for people with hearing loss will also benefit those with tinnitus and hyperacusis.

Environmental modifications are often needed to allow people with disabilities to function independently. For example, people with musculoskeletal or neurological disorders impairing mobility did not obtain independent function until architectural modifications required by the ADA were implemented. Simple design changes, e.g., lever-style door handles, lower light switches, wheelchair ramps, curb cuts, and accessible toilet compartments, allowed them independent mobility.

Environmental modifications meant to help the disabled actually help everyone. For example, the ADA modifications for people with mobility disorders allow everyone to more easily open doors with lever style handles. Wider corridors allow people to pass each other more easily. Wheelchair ramps or curb cuts help not only wheelchair users but also parents pushing a baby stroller, or delivery workers with packages on carts and repair workers with wheeled equipment. Flat entryways with doors that open automatically when someone approaches are even better, making ingress and egress easy for all.

Improved access for people auditory disorders requires quiet conditions in public accommodations. Quiet conditions will benefit everyone by making it easier to converse. Reducing ambient noise levels will likely require government action, as did implementing architectural changes needed to make public accommodations accessible to those with impaired mobility. Existing standards for classroom acoustics could be adapted for restaurants, retail stores, and malls. Alternatively, laws and regulations could specify a functional measure, e.g., indoor sound levels low enough to allow persons "to converse without straining to speak or to be heard." This is approximately 70-75 dBA. To meet the needs of those with hearing loss, a 60 dBA standard may be needed, with short reverberation times.

Enforcement is potentially easy with crowd-sourced measurement and reporting. Almost three quarters of Americans have smart phones, and accurate sound
level meter apps are available to document sound levels and the date, time, and location of the recording. [63,64] With appropriate enabling legislation, sound level recordings made by restaurant or retail patrons 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 [65]: 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. [66] Relatively inexpensive retrofitting solutions- e.g., ceiling panels, wall hangings, carpets, drapery- can help control noise and reduce reverberation. The simplest environmental modification costs nothing: turn down the amplified sound.

Those with auditory disabilities don’t need special treatment to participate fully and equally in public life. They need quiet spaces designed to be free of auditory barriers. Design for everybody- old, young, fully able or disabled- is called universal design. [67] For auditory disorders, this is UDQ, Universal Design for Quiet. Reducing ambient noise benefits all, and helps prevent future hearing loss, tinnitus, and hyperacusis in those without auditory disorders. Universal design for quiet is simple. The basic principle, adopted from the Nuclear Regulatory Commission for radiation exposure, should be ALARA: As Low As Reasonably Achievable. The goal should be quiet, rather than noise.

If the US Department of Justice Disability Rights Section and/or the US Access Board fail to act to provide more protection for individuals with auditory disabilities by requiring lower ambient noise levels in public places, legal action by individuals and/or by advocacy groups may be necessary. The American legal system is complex and it is not clear whether class action suits, in state or federal courts, or filings against public accommodations by individuals affected by too-loud ambient noise, will be most effective. Such suits have been successful at forcing cities and businesses to comply with ignored provisions of disability protections for people with mobility disorders, and will likely be successful in making indoor spaces quieter to protect those with auditory disorders.

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