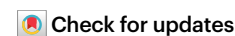


# Planning to accommodate war-induced tinnitus and hearing loss in Ukraine

Nathan Hutson, Gala Korniyenko & King Chung



The war in Ukraine is having many indelible impacts, including hearing loss and tinnitus for soldiers and civilians. Urban planning interventions will be essential to accommodate the large scale of post-war hearing disability in Ukrainian cities.

When the guns fall silent in Ukraine, they will not fall silent for everyone. Hundreds of thousands of Ukrainians will likely be left with substantial hearing impairment and/or tinnitus resulting from military activity and incessant air raid sirens. We urge the Ukrainian government, in partnership with international sponsors, to begin the difficult task of predicting the net impact of war-related activities on the population's hearing health. Such an assessment will allow Ukrainian cities to implement mitigation strategies while the war is ongoing and incorporate appropriate accommodations into their urban form during the rebuilding process.

Sound has long been used as a weapon of war for both physical and psychological ends. In recent history, its use has run the gamut from soldiers in Vietnam blasting rock music at the Viet Cong to more sophisticated 'sound bombs' used extensively by Israel in the Gaza Strip<sup>1</sup>. The term 'beliphonic sounds' was introduced by Daughtry to describe the cumulative impact of sounds experienced in war and their multifaceted impacts on post-conflict society<sup>2</sup>.

Hearing loss means a diminished functional acuity to sounds that reduces our ability to hear soft sounds, whereas tinnitus refers to an incessant ringing in the ears in the absence of such sounds in the environment that often results from repeated exposure to noise levels higher than an 85 dB sound pressure level. Both are recognized by the World Health Organization as a significant category of disability with substantial impacts on quality of life, workplace productivity, cognitive function and learning<sup>3</sup>. Nearly 20% of the world's population has some degree of hearing loss, and an estimated 14% [have diagnosed or undiagnosed tinnitus](#). Because of the consistency of noise exposure associated with weapons discharge, servicewomen and servicemen are 30% more likely to develop severe hearing loss than non-military populations<sup>4</sup>. Tinnitus is particularly associated with the military and has been identified as the number one service-related disability in the United States. For this reason, the US Department of Defense and Department of Veterans Affairs have invested millions of dollars in research and [treatment for veterans](#) with hearing loss and other disabilities.

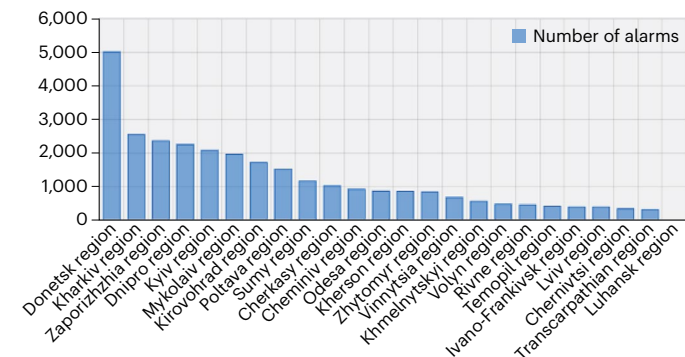
Much of this research would be transferable to the Ukrainian context, in which both service personnel and civilians have undergone persistent exposure to stressful levels of sound that can inflict significant physical and psychological damage<sup>5-7</sup>. The women and men serving at the front of what has become the most artillery-heavy



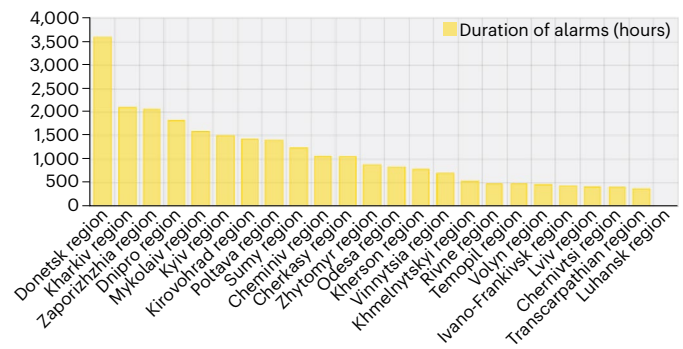
**Fig. 1 | Ukrainian soldiers fire with D-30 artillery at Russian positions in the direction of Klishchiivka. Donetsk Oblast, Ukraine, 13 August 2023.**

conflict in modern memory must fire thousands of artillery shells daily to hold back the Russian assault. In the early days of the war, Ukraine's allies transferred massive volumes of howitzer artillery, which proved militarily effective but can produce an auditory nightmare when fired without acoustic protection (Fig. 1). Specifically, the acoustic trauma from the combination of sound and shock waves can create structural and/or functional damage to the outer ear (for example, perforation of the tympanic membrane), the middle ear (for example, disarticulation of the three smallest bones, known as the ossicular chain) and the inner ear (for example, damage to the hair cells and the structure of the organ of Corti). Without the proper hearing protection, soldiers can experience permanent damage in a single exposure or within days or weeks. Video clips of Ukrainian soldiers firing artillery while desperately and belatedly attempting to block their ears are, to any trained audiologist, a horror reel.

This mismatch of armament and hearing protection was understandable in the war's early days. The need for rapid responses to the invasion and the speed at which NATO equipment was deployed to interdict the existential threat made long-term mitigation of hearing damage a low priority. Now, after two years of relentless war, it is becoming clear that Ukraine will soon need to accommodate a large number of hearing-impaired veterans in its cities. Furthermore, civilians have not been spared. The frequency and duration of air raid sirens have exposed millions of adults and children to rock concert-level sounds daily. These sirens often use high-frequency sounds and endanger the very frequencies that cause tinnitus. Concussive impacts from nearby explosions and collapsing buildings can cause temporal bone or other skull fractures and compromise the fragile structures of the ear. Depending on the sound pressure exposure levels and frequencies,



**Fig. 2 | Number of alarms per region.** Source: <https://air-alarms.in.ua/en>.



**Fig. 3 | Hours of alarm per region.** Source: <https://air-alarms.in.ua/en>.

people in the war zone may develop not only hearing loss and tinnitus but also a range of associated problems including traumatic brain injuries, post-traumatic stress disorder, hyperacusis (hypersensitivity to sounds) and misophonia (intense negative psychological reactions to certain sounds that may be associated with traumatic events). Preparing Ukrainian cities to accommodate the reality of this sometimes-hidden disability means first understanding its magnitude and devising context-specific mitigation strategies.

### Assessing the net effect

Research on Ukrainian refugees in Poland has already measured a high incidence of hearing loss, even amongst those who fled during the war's early days<sup>8,9</sup>. While a comprehensive assessment of cumulative hearing damage is currently impossible, the aggregate level of exposure indicates where needs are greatest. Volunteer organizations have documented 29,359 air raid sirens since 24 February 2022. There is a substantial difference in exposure by region; 11 regions in Ukraine have endured at least 1,000 hours of alarms (Figs. 2 and 3). These alarms are specifically designed to aggravate and thereby induce the population to seek a quieter place, meaning they are most damaging at the beginning of their cycle.

As Kyiv has a small and densely populated territory, each alarm is experienced by the majority of its 2.9 million residents. In this case, if we are to assume that 80% of Kyiv's population has endured the reported 834 alarm events (234 hours of cumulative alarm duration), this would result in a net exposure since the invasion began of 543 million person-hours of exposure of varying degrees. The data also record 6,120 discrete explosions in civilian areas, including incoming artillery, drone and missile attacks.

Assessing the impacts on servicemen and servicewomen is also an inexact science. On average, the Ukrainian army has fired 7,000 artillery shells daily since the war began, with some systems producing 181 dB per discharge.

### Planning interventions and recommendations

In the short term, the Ukrainian military must ensure that soldiers are equipped with hearing protection while cities should assess the intensity, frequency and duration of air raid sirens. Given the substantial effort of the US Department of Defense and National Institutes of Health in diagnosing, treating and preventing hearing loss and tinnitus, they are natural partners for Ukraine's effort in estimating its needs and measuring the frequency and severity of exposure. Prognosis for future diagnosis requires comprehensive surveys and objective tests

of service members and civilians to document their symptoms, their exposure and the effects of hearing impairment in their daily lives.

In the longer-term, urban planning interventions must steer Ukraine's recovery to accommodate a mentally and physically traumatized population, particularly within public spaces<sup>10,11</sup>. While tinnitus has no cure, several management techniques and strategies have been shown effective in mitigating symptoms in some people and in minimizing the negative impact of tinnitus<sup>3,12</sup>. Hearing care services such as hearing aids with tinnitus management technologies, hearing health surveillance and accommodation measures will be critical to help both civilians and military personnel in the post-war recovery.

Urban planners increasingly recognize that the ambient noise of a large, bustling city that may be exciting for some can be physically or psychologically burdensome for others. Creating new green and blue spaces – that is, areas of open space that can break up the bustle of a city – has recently been demonstrated as a key accommodation technique for addressing post-traumatic stress disorder and related mental health challenges<sup>13</sup>. Populations with autism and other neurodivergences benefit from planning modifications that reduce or redirect excessive stimulation, particularly those involving sound<sup>14</sup>. In this way, it may turn out that the modifications to accommodate hearing loss and tinnitus may dovetail with interventions that address emotional trauma.

Kyiv has suffered less damage and is predicted to see the greatest inflow of new residents, including those with hearing impairment, after the war owing to the centralized provision of international aid. Thus, on the basis of the existing literature and known impacts so far, the following accommodations and planning interventions could include soft infrastructure and engineering controls to reduce ambient noises in schools, public places, transportation stations and homes, along with visual displays for essential information. Implementation of hearing loop systems can reduce the interference of background noise and reverberation and allow users to receive announcements directly to their hearing devices. Cities like Mariupol, as a result of the extent of damage suffered, can now reimagine their entire urban form with a focus on accommodation. Mariupol will likely host one of the largest percentages of impaired population owing to the severity of its destruction and proximity to the front line.

We have only begun to assess the spectrum of impact wrought throughout Ukrainian society by Russia's invasion. Only through a sustained and concerted effort can Ukraine ensure that the war will not impede citizens' ability to communicate and that freedom from war will not come at the price of freedom from auditory peace.

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## References

1. Goodman, S. *Sonic Warfare: Sound, Affect, and the Ecology of Fear* (MIT Press, 2012).
2. Daughtry, J. M. *Listening to War: Sound, Music, Trauma, and Survival in Wartime Iraq* (Oxford Univ. Press, 2015).
3. Zenner, H. P. et al. *Eur. Arch. Otorhinolaryngol.* **274**, 2079–2091 (2017).
4. Yong, J. S. E. & Wang, D. Y. *Mil. Med. Res.* **2**, 6 (2015).
5. Eggermont, J. J. & Roberts, L. E. *Trends Neurosci.* **27**, 676–682 (2004).

6. Parker, J. E. K. *Sound Stud.* **5**, 72–96 (2019).
7. Ouzounian, G. *Stereophonica: Sound and Space in Science, Technology, and the Arts* (MIT Press, 2021).
8. Chung, K. & The Heart of Hearing Team. *Hearing J.* **76**, 26–27 (2022).
9. Chung, K. et al. A hearing report from Poland. *Audiol. Today* **35**, 42–53 (2023).
10. Korniyenko, G., Kovalyshena, I. & Schebetyuk, D. In *Inclusive Practices, Equity and Access for Individuals with Disabilities: Insights from Educators across World* (eds Argyropoulos, V. & Halder, S.) 89–107 (Palgrave, 2019).
11. Stafford, L., Vanik, L. & Bates, L. K. *Planning Theory Practice* **23**, 101–142 (2022).
12. Han, M., Yang, X. & Lv, J. *Am. J. Otolaryngol.* **42**, 103151 (2021).
13. Geary, R. S. et al. *Lancet Planet. Health* **7**, e809–e818 (2023).
14. Korniyenko, G. & Pisha, A. *Ground Up* **11**, 47–51 (2022).

## Competing interests

The authors declare no competing interests

## Additional information

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