
Loud sounds can cause hearing loss and affect your overall health, but quieter but constant sounds may also keep our brains in a constant state of alarm. ***By Nina Kraus, Ph.D.***

My Italian home base, Trieste, is near the Dolomite mountains. I have hiked there all my life. One recent spring, after a long ascent, my cousin Lucio and I sat at the top of the world, looking at the peaks and valleys around us and listening. I lay back in the grass. After about 10 minutes of just being, I said something to Lucio. When I broke the silence, the loudness of my voice was jarring. The lack of noise called for a recalibration of listening.

The "sound mind"—sound, and what our brains do with it—accomplishes the herculean task of turning air movement into sensation, sound into meaning, on a routine basis. But what about the sounds that serve as obstacles to our extracting meaning from intended sounds? One of the impediments that gets in the way of our well-tuned auditory system—and it is a big one—is noise. I'm talking about noise in its usual sense of unwanted sound outside the head. But we also experience noise inside the head—the conditions that impede the sound mind from efficiently doing its job. What, if anything, can we do to combat it?

We need to be less cavalier about the day-to-day commotion that surrounds us in our raucous world. These noises do not meet or exceed the generally accepted threshold of "unsafe." They are not novel and alerting; rather, they are ongoing and have generally consistent acoustic properties over time, and hence, they do not convey much information. These are the sorts of sounds most would consider "background noise." For this reason, we tend to ignore them. We tune them out. But are we really tuning them out, or are we simply living our lives in a constant state of alarm?

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Difficulty understanding speech in noise after exposure to moderate levels of noise can emerge in people with typical hearing thresholds. Moreover, a noisy environment has many underrecognized negative impacts that have little to do with hearing per se.

Chronic noise exposure—for example, such as might be experienced by individuals who live near an airport—can lead to an overall decrease in perceived quality of life, increased stress levels along with an increase in the stress hormone cortisol, problems with memory and learning, difficulty performing challenging tasks, and even stiffening of blood vessels and other cardiovascular diseases. According to the World Health Organization noise exposure and its secondary outcomes such as hypertension and reduced cognitive performance are estimated to account for an astounding number of years lost due to ill health, disability, or early death.

Noise disturbs learning and concentration. Students attending public schools in New York City had markedly different reading outcomes depending on whether their classroom was on the side of the school that fronted a busy elevated train track or on the other side of the school, which was shielded from the train noise. Students on the noisy side lagged three to eleven months behind their peers in reading. In the wake of these findings, the New York Transit Authority installed rubber padding on the railroad tracks near the school and the Board of Education installed noise-abatement material in the noisiest classrooms, together reducing noise levels by about 6–8 decibels (dB). The reading-level difference soon vanished.

The effect of noise is not limited to auditory or language tasks like reading. In one experiment, subjects were asked to track a visual target, a moving ball, on a computer screen with a mouse. Meanwhile, other balls were simultaneously roving around on the screen. Participants who had experienced long-term noise exposure as part of their occupation had a more difficult time with the task, especially when the task itself was accompanied by random noises; they were slower and unable to keep as close to the target ball.

In "Why We Sleep," UC Berkeley sleep scientist Matthew Walker calls the lack of proper sleep "the greatest public health challenge we face in the 21st century." Sleep is becoming more recognized as crucial for our health, as it affects our cardiovascular system, our immune system, and our ability to think.

Noise is one of the biggest culprits keeping us from a good night's rest. Noise—even at fairly low sound levels—has a harmful impact on quantity and quality of sleep. Noise keeps us awake longer and awakens us earlier. While sleeping, noise in the environment affects the quality of sleep, prompting body movements, awakenings, and increased heart rate. Traffic noise can shorten periods of REM (dream) and slow-wave (deep) sleep, and diminish

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In our waking lives, the insult of "safe" noise to the sound mind can be especially pernicious for children. Children are masters of language learning. Parents are gobsmacked at the short amount of time that elapses between observing their child say their first word to their speaking in full sentences. Sound to meaning connections are formed with great rapidity. Children cannot help learning the languages they are exposed to—even more than one. But what if the sounds children are exposed to at this critical age are meaningless?

This question is difficult to address in humans because it is impossible to control noise levels adequately in a real-world setting. However, we can answer questions like this in animal experiments. By controlling the duration, intensity, and quality of sound exposure, it is possible to get a direct look at how the electrical signals—the currency of the nervous system—in the brain are affected. Just what happens to our sound minds when we are exposed to "safe" noise? And are these effects transient or permanent?

Typically, by adulthood, the auditory cortex of a rodent is organized tonotopically. (Tonotopy—think tonal topography—is the tendency for structures in the auditory pathway to be arranged topographically by preferred frequency.) However, early in life, low- and high-pitch sounds have not yet settled into their cortical homes. Developing rodents were raised in an environment with continuous 70 dB noise. (For reference, the National Institute for Occupational Safety and Health's occupational noise limit guidelines do not even go that low; 70 dB is considered a "safe" level of noise.) By the time the rodents reached maturity, their auditory cortices were still undifferentiated in terms of tonotopy; the low- to high-pitch gradient had not formed.

This raises concerns for human babies who spend time in an environment we might consider noisy but not "damagingly" noisy, like a neonatal intensive care unit (NICU). What might happen to a premature baby's auditory cortical organization as she listens to the beeps and clatters of medical monitoring systems, ventilators, and pagers rather than typical intrauterine sounds like rhythmic heartbeats, digestive noises, and the filtered voice of her mother that she would still be enjoying if born full term? Preterm infants can have a host of developmental challenges, including language and cognition, that may be exacerbated by this early noise exposure.

Scientists have introduced measures to mitigate the noisy NICU atmosphere. In one study, the sounds of the mother's heartbeat and voice were piped into the incubator. Babies with exposure to these "good" sounds along with the bad had a more fully developed auditory cortex than the infants who heard only the bad sounds. Live music performed in the NICU also stabilized babies' heartbeats, reduced stress, and fostered sleep.

Cortical map disorganization need not be permanent. In rodents whose tonotopic maps were disorganized by noise, once the noise was removed, the tonotopic organization of the cortex resumed afresh. Similarly, after noise damage, cortical map disorganization can be minimized by exposure to an enriched auditory environment—reminiscent of the positive effect of enriched sounds for babies in the NICU. The sound mind is constantly reinventing itself.

## Changing Attitudes

I have been to concerts where the musician boasts, "We're going to play so loud we'll make your ears bleed,"

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and the audience responds, "Yeah!" There is a toughness that goes along with listening to loud sounds that can be destructive. This tough attitude is not unlike how we used to think about athletics—getting back in the game immediately after getting hit in the head. "Shake it off!"

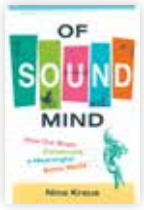
Consider seat belts and airbags in a car, or safety protection in sports. As recently as the 1970s, only a smattering of professional hockey players wore helmets, and major league baseball players would shed theirs as soon as they reached base. Today, a helmetless hockey player seems inconceivable. Baseball players wear their helmets while on the base paths and varieties with extended jaw guards have become the norm. We now appreciate the importance of protecting ourselves against concussions. Today, even most macho halfwits wear seatbelts, and more attention is being paid to safety in sports even to the extent that, for better or worse, contact sports are on the wane. It is my hope that we stop being so cavalier about noise in the same way.

Attitude changes are in the air. People like Gordon Hempton in Los Angeles, with his Quiet Parks International initiative, are working to preserve silent spaces. People everywhere noticed and appreciated the reduced sound levels during the coronavirus shutdown. When noisy life resumed in Paris, noise complaints increased, especially about noisy motorbikes. Police antinoise brigades stepped up their patrols and street corner noise sensors were installed to issue automatic fines to motorbikes exceeding permitted noise levels.

*Our sound minds affect the choices we make in our sonic world.* The less we appreciate silence and the more our brains become accustomed to noise, the noisier the world will get. A vicious cycle.

Sound is an invisible ally and enemy of brain health. Our engagement with sound leaves a fundamental imprint on who we are. The sounds of our lives shape our brains, for better and for worse.

And our sound minds, in turn, impact our sonic world, again for better and for worse. Will we be expert listeners or poor listeners? As a consequence of what we value in sound, how will we build the sonic world we live in? A holistic understanding of the biological consequences of our lives in sound positions us to make better choices for ourselves, for our children, and for society.




*This is excerpted from "Of Sound Mind: How Our Brain Constructs a Meaningful Sonic World," by Nina Kraus, Ph.D. Reprinted with permission from The MIT Press. Copyright September 2021. A neuroscientist who has done groundbreaking research on sound and hearing for more than 30 years, Kraus is the Hugh Knowles Professor of Neurobiology, Communication Sciences, and Otolaryngology at Northwestern University in Illinois.*

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