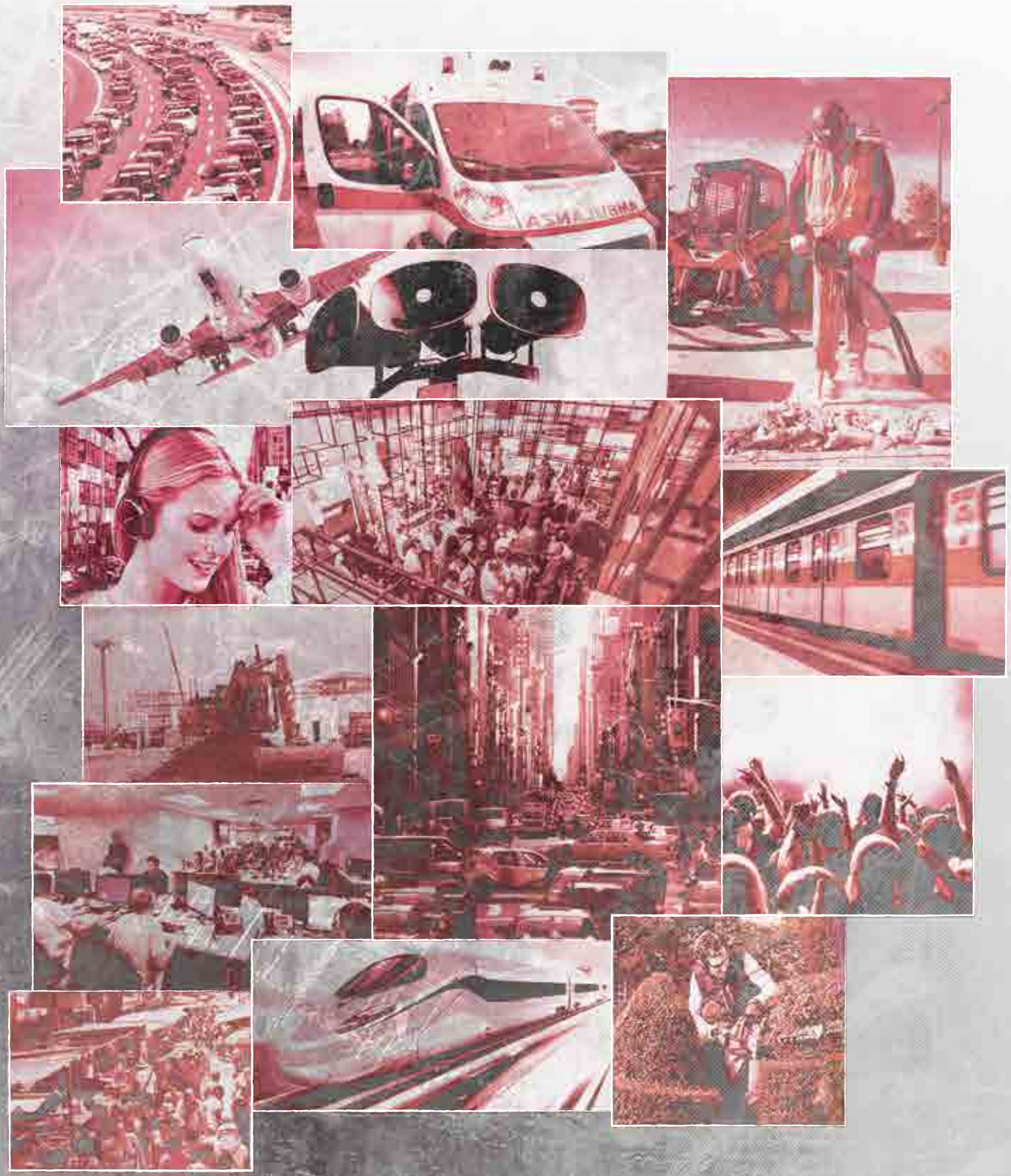
Coping with noise

Consensus Paper on the effects of noise in the world



Introduction

Methodology
This paper is a result of a critical assessment of data recorded in a recent survey obtained from GfK Eurisko and promoted by Amplifon, based on responses from 8,800 people from 11 countries. The study was designed to gather information about the relationship between exposure to noise and its effects on health, which range from those on hearing to the impact on general physical and psychological wellbeing. Survey results were discussed during a round table conference among experts, and were completed by a review of recent scientific literature on the topic.

Work Group
The Consensus Paper on noise and the possible actions individuals and the community can put in place to manage it and minimise its damaging effects was drawn up by a working group, who met in Milan in May 2015. The group was composed of:
Roberto Albera, Professor of Otorhinolaryngology, Department of Surgical Sciences, University of Turin – **Brian C. J. Moore**, Professor of Auditory Perception, Department of Psychology, University of Cambridge – **Giampaolo Nuvolati**, Professor of Urban Sociology, Department of Sociology and Social Research, University of Milan-Bicocca – **Carlo Ratti**, MIT Senseable City Lab – **Stephen A. Stansfeld**, Professor of Psychiatry, Queen Mary University of London.
After the worktable, the Consensus Paper was enriched with another contribution written by: **Giancarlo Cianfrone**, Sense Organ Department, La Sapienza University of Rome – **Valeria Testugini**, AIRS Onlus - Italian Association for the Research on Deafness.

Contents

This publication was made possible thanks to Amplifon's contribution.

Summary

In today's world, noise is an intrinsic part of most people's lives. Expanding urbanisation and changes in habits and lifestyle continuously expose us to more or less invasive noise 24 hours a day, whether at the workplace or on the street, in public venues or during our leisure time, perhaps even when we listen to music via earphones.
Persistent intense sounds can have harmful effects on many bodily organs and systems.

Several studies have proven that, besides being harmful to hearing, noise:

- increases the risk of mood swings, anxiety, irritability and nervousness;
- renders more probable the onset of sleep disorders, such as insomnia, and headache;
- has negative effects on the cardiovascular system and on body weight.

These effects have been confirmed by a recent international survey conducted by GfK Eurisko, based on responses from 8,800 people from 47 cities throughout 11 countries. The study reveals that "noise sickness" is increasing worldwide in large cities, while awareness of the possible damage to health or of the precautions required to reduce risks is still quite inadequate.

This Consensus Paper has been developed through a critical assessment of the survey data integrated with a review of the latest scientific literature and is designed to provide information about the effects of noise and the body's reactions to excessive exposure to noise and to suggest prevention methods for both individuals and society in general. Moreover, the document demonstrates that each person copes with noise in different ways, and to different extents. This document is also intended to provide those who already have hearing loss with the tools to handle excessive noise and thus maintain a good quality of life.

Noise sickness

Edited by:
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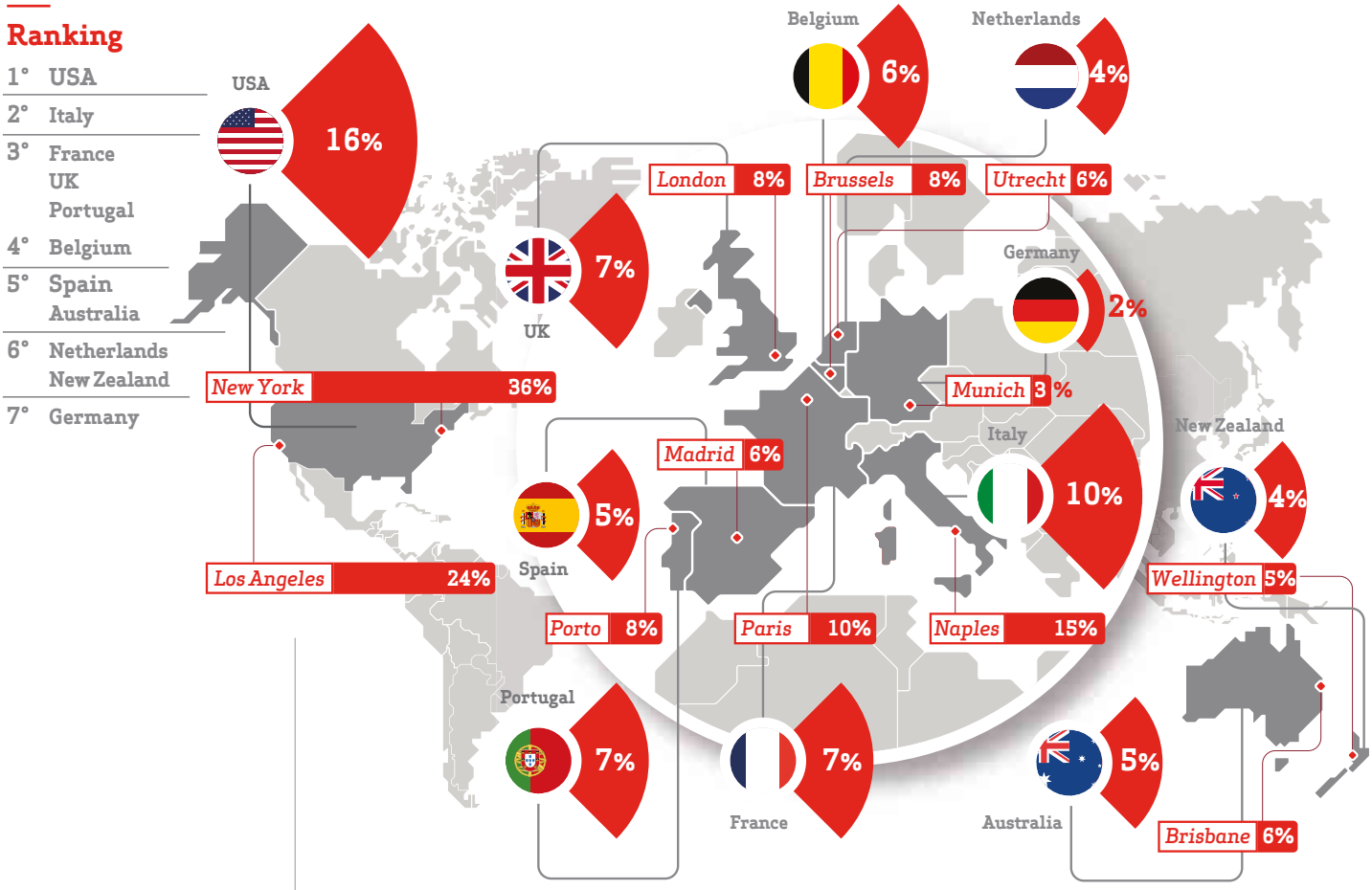
We are surrounded by noise; it is everywhere, in busy city life and even at home. Intense sounds may come from the radio and television, from the earphones we use to listen to music, and from domestic appliances. We often have to make an effort to follow a conversation at a restaurant, and we may be overwhelmed by the roaring sound of road traffic. Many people feel overwhelmed by invasive persistent noise during the day and even at night, not only at nightclubs or in crowded haunts but also in the workplace. In the long run this can have several effects on health and wellbeing, a genuine "noise sickness."

With the aim of better understanding the type and number of sounds we are exposed to and, especially, their impact on health, a recent survey was carried out by GfK Eurisko involving 8,800 adults to represent the general population of 47 cities in 11 countries, specifically Italy, France, Germany, the Netherlands, Belgium, the United Kingdom, Spain, Portugal, the United States, Australia and New Zealand. The sounds people are most often exposed to and which cause the greatest annoyance are headed by outdoor sounds, noise from the street and public transport (83%), followed by music, TV and radio at full volume (42%), by conversations between groups of people (28%) and by the noise of domestic appliances at home (20%). Younger generations generally have to face a greater amount of noise than people aged over 55, who seem to somehow avoid most situations that might expose them to excessive noise. However, not all the world is equally noisy. As a matter of fact, the United States and Italy show a higher noise exposure average than other countries, according to the persons interviewed. On the other hand, Germany and the Netherlands are assessed as the quietest countries. The quietness of the latter probably results from better control of noise sources. One out of three people judges that exposure to noise has generally increased in recent years, with the percentage being highest at 41% in Italy and lowest at 29% in the Netherlands.

The United States and Italy show a higher noise exposure average than other countries according to the persons interviewed; Germany and the Netherlands are assessed as the quietest ones.



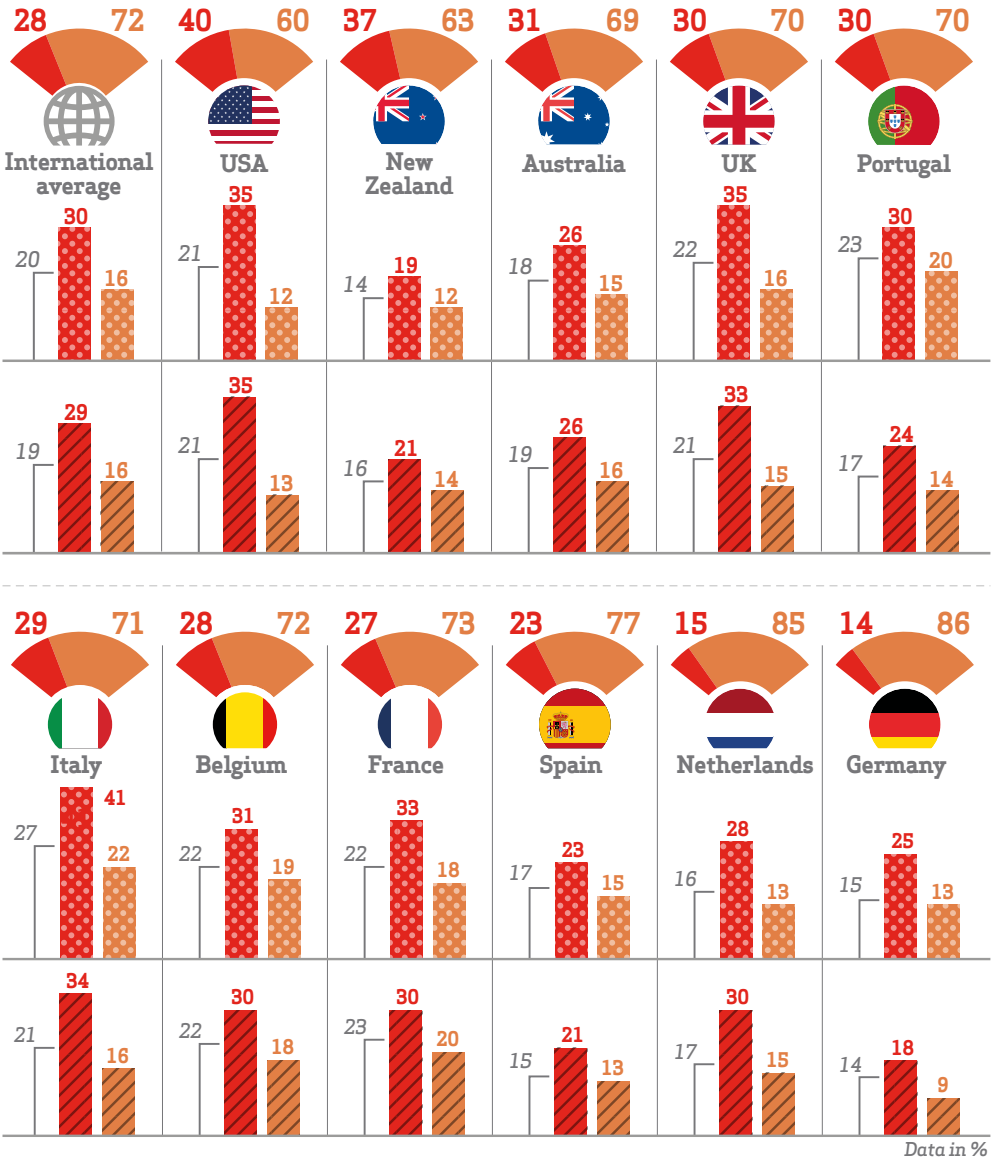
INFOGRAPHIC 1
The Exposure Noise Pollution Index (ENPI) evaluates the perception of noise exposure in 11 countries all over the world. ENPI evaluates the amount, recurrence and length of the noises to which people are exposed to in big cities.
The map represents the percentages of high noise exposure and highlights the noisiest city in each country involved in the survey[1]

The Exposure Noise Pollution Index (ENPI) was defined by considering the number, frequency and length of exposure to unpleasant noises and was classified as high, medium-high, medium-low, or low. It is high if a person is exposed to more than nine (>9) types of noise for more than eight hours a day, medium-high for exposure to 2-9 noises for more than eight hours a day, medium-low for 2-9 noises for less than eight hours a day, and low with 0-1 noises a day. The data collected indicate that, on average, 28% of the population have a high or medium-high ENPI. The Index drops to 18% among people aged over 55, and there are considerable differences between countries, shifting from a maximum of 40% in the population with high or medium-high ENPI in the United States, to a minimum of 14-15% in Germany and The Netherlands. In The Hague barely 9% of the inhabitants have a high or medium-high ENPI, while the percentage is 13% for Hamburg, 32% for Naples, 45% for Los Angeles and a remarkable 55% for New York.

The survey allowed us to assess the correlation between citizens' perception of noise exposure and several disorders. The results show that a high or medium-high level of exposure to noise, registered in 28% of the population, approximately doubles the rate of reported irritability, mood swings, nervousness and worry. Likewise, increased noise exposure

was associated with an almost doubled rate of reported insomnia and sleep disorders, concentration problems and headaches. New York is the city with the highest noise exposure and the worst impact on psychological and physical wellbeing, followed by Naples, London, Paris and Brussels.

The countries where the relation between noise exposure and worsened mood and psychophysical wellbeing is more evident are the United States, the United Kingdom, Italy and Belgium. Germany, The Netherlands and Spain seem to be less affected, as they generally have lower levels of exposure to excessive noise. Australia and New Zealand are the only countries with high exposure to noise but low impact on mood and health.



KEY

People exposed to high and medium-high noise

People least exposed to noise

Average

Negative moods: irritability, nervousness, mood swings

Other diseases: insomnia, sleep disorders, problems concentrating, headaches

Negative moods: irritability, nervousness, mood swings

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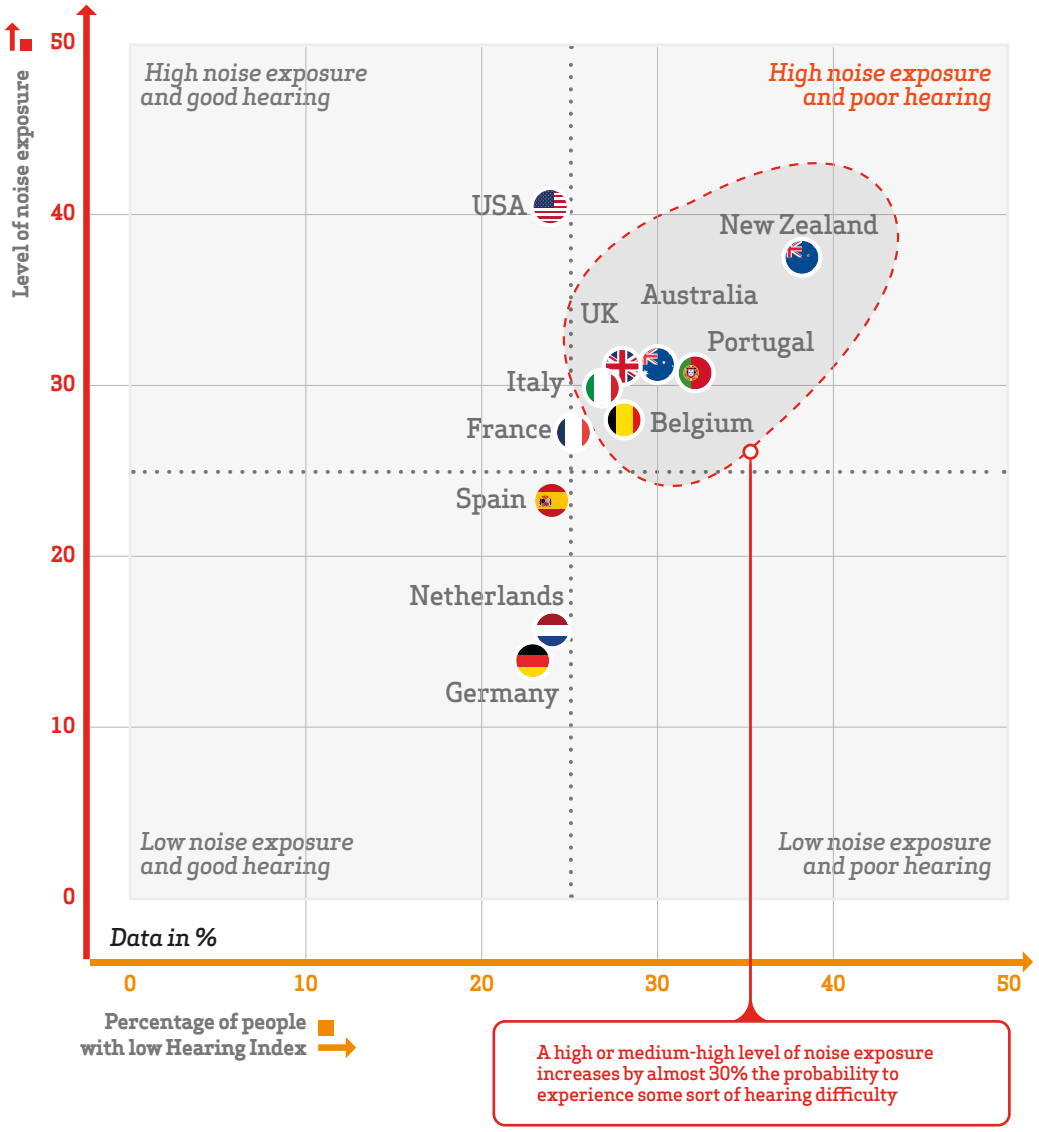
INFOGRAPHIC 2
A high or medium-high level of exposure to noise approximately doubles the rate of reported irritability, mood swings, nervousness and worry. Increased noise exposure was associated with an almost doubled rate of reported insomnia and sleep disorders, concentration problems and headaches[1]

The link between the ENPI and hearing is equally evident. The Hearing Index, which takes into account parameters such as the capacity to accept background noise during a conversation, to understand a person talking when there is a lot of background noise present, or to properly hear a person talking in a fairly quiet room, is better in more "quiet" countries such as Germany, where 23% of the population has a good Hearing Index, compared to a mean of 18% for all other countries. An average of about one in three people claim to have less than perfect hearing. In fact, 28% of the people interviewed have a poor Hearing Index, which indicates impaired hearing, with peaks of 34% in the over-55s.

The data clearly indicate that an increase in ENPI, and thus in the percentage of people most exposed to noise, results in an equivalent increase in the percentage of the population with a low Hearing Index: a high ENPI increases the probability of experiencing some sort of hearing difficulty by almost 30%. The impact of noise pollution on hearing loss is particularly high in New Zealand, Australia, Portugal, the United Kingdom and Belgium.



INFOGRAPHIC 3
The figure shows the relationship between level of noise exposure and the percentage of people with a low Hearing Index[1]

The data are in keeping with the scientific literature published on this topic. It has long been known that noise bothers and annoys people because it is experienced as an intrusion into daily life[2], with greater effects as the intensity of sound increases[3]. Excessive noise has also been associated with rising rates of anxiety disorder[4,5], with a 60% rise in prescriptions for tranquillisers[6], and the onset of sleep disorders[7,8]. Exposure to noise, especially at night time and leading to difficulties in sleeping properly, may trigger a sort of chain reaction that is hazardous to health. An example of this possible chain reaction is illustrated in Figure 1. Noise from aircraft flyovers increases cardiovascular risk with a mean 6 mm Hg increase in blood pressure recorded after exposure to intense noise during sleep[9]. It has been theorised that noise, especially at night, causes a rise in the production of stress hormones, which is harmful when it occurs during sleep, as it is known to affect heart and blood vessel function. Hence, stress hormones can have a direct negative effect on the cardiovascular system. Noise pollution is deemed a cardiovascular risk factor in several recent studies, which have proven that noise, especially when caused by traffic and vicinity to airports, increases blood pressure[10] and the risk of myocardial infarction[11], stroke[12], admissions to hospital[13] and mortality[14] associated with cardiovascular causes.

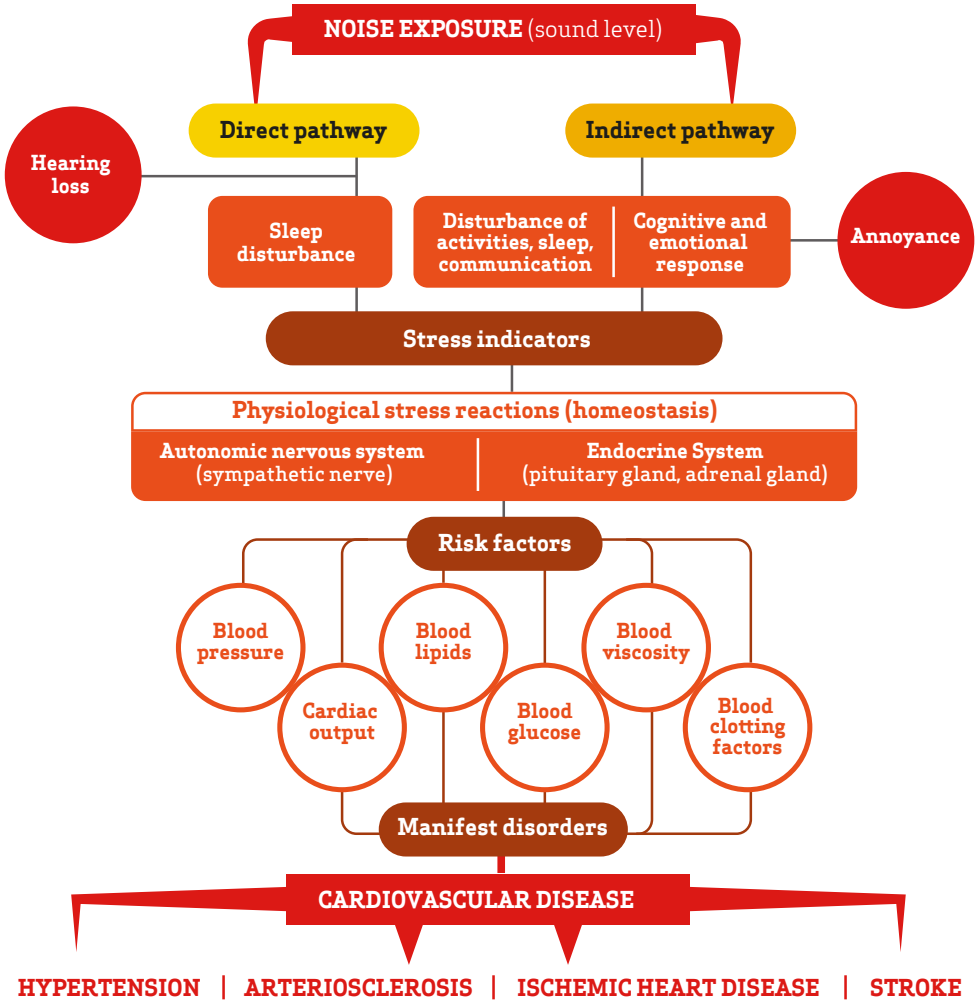


Figure 1
Noise reaction model according to Babisch (2014)[20]

Data reveal that the risk of hypertension, for instance, rises by 10-30% for every 5 decibel increase in noise level[15]. Moreover, as reported in a recently published study, a mere 5 decibel reduction in noise would suffice to reduce the incidence of hypertension by 1.4% and that of coronary disease and heart attacks by 1.8%[16]. In Italy, for instance, this would mean a reduction of over 200,000 cases of hypertension and at least 2,000 fewer cases of cardiac arrest[16]. Furthermore, a recent study published by the European Heart Journal, based on the 8.6 million London population, reported that in areas where daytime road traffic noise exceeded 60 decibels (dBA) there were 4% more deaths and a 5% increase in stroke risk than in quieter areas, where the noise level was below 55 dBA; and the risk of being admitted to hospital with a stroke rose to 9% among the elderly[17]. Finally, studies report that environmental exposure to noise is related to an approximate 10-15% increase in the probability of developing diabetes over a period of 5 years[18]. Every 5 decibel increase in noise level is associated with an 18% rise in the risk of central obesity and a 29% increment in the risk of developing too large a waist, both indicators of greater cardiovascular and metabolic risk, although this result is not consistent across all studies[19,20].

The damage excessive noise causes to hearing has also been ascertained. Frequent, prolonged exposure to noise with levels above 75-85 decibels (dBA) damages the hair cells of the inner ear, leading to an irreversible chronic condition (a list of the most common sound levels is reported in Table I). When we are exposed to intense sounds, our sensitivity for detecting weak sounds decreases. The "threshold shift" produced by a single exposure generally disappears after a few hours, if one returns to a quiet environment, so it is often called "temporary threshold shift" (TTS); however, if exposure to noise is repeated, the loss of sensitivity may become permanent. In the past, it was commonly believed that if a threshold shift was temporary, then no permanent damage had been done to hearing. However, new experimental observations suggest that exposure to noise can damage the nerve fibres that make up the auditory nerve even when the noise only produces TTS[21]. This leads to a form of hearing damage that is not revealed by the traditional clinical measure of hearing – the audiogram.

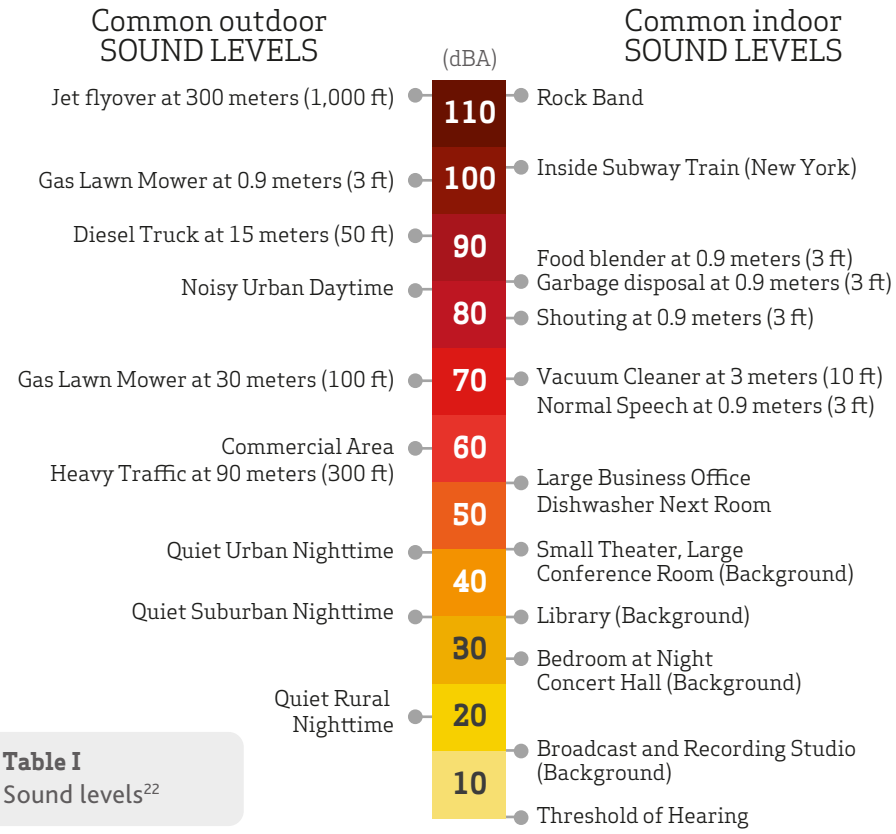


Table I
Sound levels[22]

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A contemporary challenge

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Urbanization is one of the major causes of increased exposure to excessive noise and today's lifestyles also play their part in surrounding us with continuous loud background noise.

Noise was not an issue in rural societies before the industrial revolution. It has become pervasive in the modern world, and is a growing problem of contemporary life. Urbanisation is one of the major causes of increased exposure to excessive noise but today's lifestyles also play their part in surrounding us with continuous loud background noise. As confirmed by data from the GfK Eurisko survey, metropolitan areas are invariably noisy. In New York City, the city that never sleeps, the perception of over exposure to very loud noise is higher than elsewhere. As long ago as the 1950s it was observed that the audiometric threshold of the lowest detectable sound intensity was higher for inhabitants of urban rather than rural settings (Figure 2). Since then noise pollution has further increased, and young people studied in the mid-20th century had better audiometric thresholds than those of the same age assessed during subsequent decades. This phenomenon, known as sociocusis (non-occupational hearing loss), affects a growing number of people, not least due to the rising number of exposed people as urbanisation increases. The severity of noise-induced discomfort also escalates as cities expand in size. As a matter of fact, 51% of inhabitants of metropolitan areas consider noise a problem, versus 9% of those who live in municipalities with fewer than two thousand inhabitants[1].

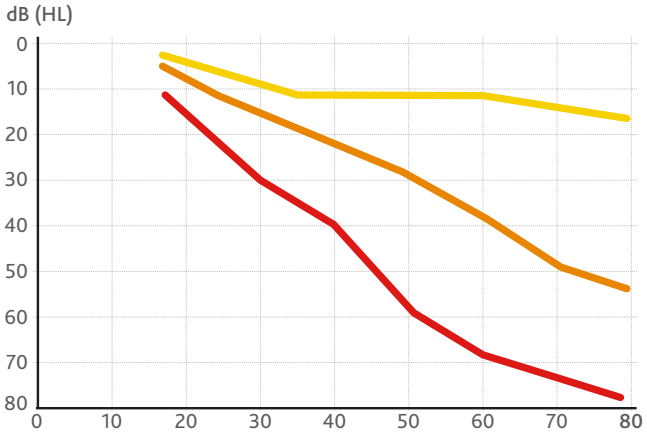

Figure 2
Age-based mean audiometric threshold at high frequencies [2]

in an African population with very low noise exposure

in a population living in a farming environment

in an urban population in the '50s

The lifestyles developed along with urbanisation and modernity have made the problem worse. In fact, damage to hearing is aggravated by factors such as alcoholism, smoking, obesity, hypertension, diabetes and high cholesterol, all of which have a higher incidence today than in the past. Furthermore, the use of music has changed considerably. Over the past 40 years, nightclubs have reached noise levels that can damage the hearing of anyone frequenting them regularly for long periods of time[3,4]. The habit of listening to music through earphones has become a mass phenomenon, especially during the past 20 years. Some devices can produce maximum sound levels of 120 decibels (dB SPL), and habitual listening for a prolonged period of time may occur using levels of about 100 dB SPL. About 90% of youngsters aged 12-19 years use music players. Half of them admit keeping the volume high, and one out of three says he/she uses the devices very often. There is a close correlation between the duration of use and the audiometric threshold; the longer the exposure to music through earphones, the greater the hearing loss (Figure 3). Injuries are particularly significant in the most susceptible subjects, who suffer considerable yet subtle damage caused by noise[5,6]. The hearing deficit evolves slowly and progressively. Therefore it is often unrecognized, at least in the early stages[7,8].

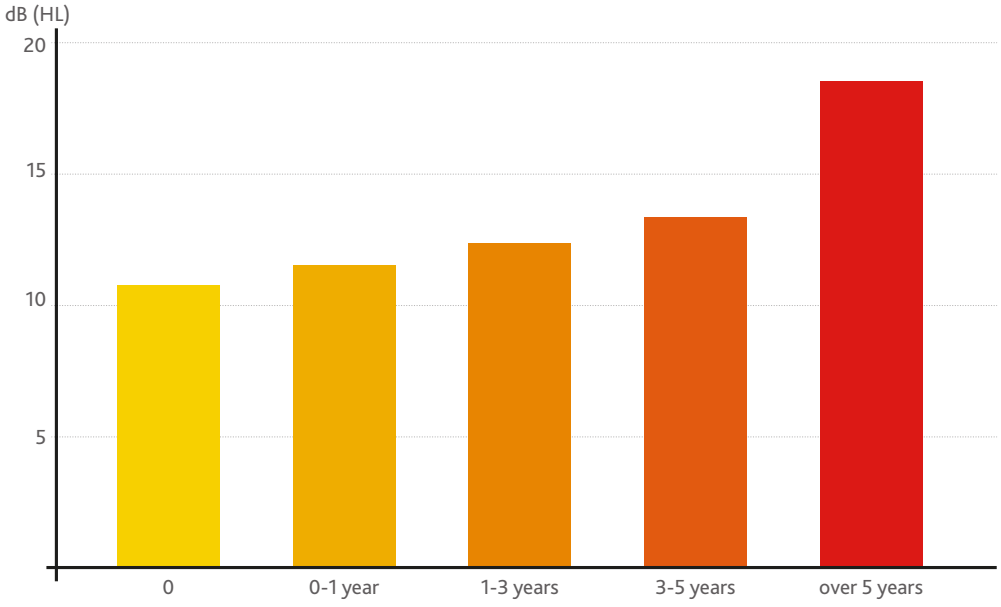

Figure 3
Mean audiometric threshold in young people who use MP3 players, broken down by the duration of use[8]

The duration of use of earphones to listen to music and the audiometric threshold are closely correlated: the longer the exposure to music through earphones, the greater the hearing loss.

Today, noise exposure is deemed safe if it does not exceed eight hours a day at a sound level below 80 decibels (dBA)[9]. This threshold level can be easily exceeded by some of the noises present in big cities for long periods of time. According to the GfK Eurisko survey data, the noise to which we are most exposed in big cities is intense, such as road traffic (80 dBA), hammer drills in construction yards (105 dBA) and ambulance sirens (115 dBA). Moreover, we are surrounded by less intense sounds that nonetheless create continuous background noise, ranging from ringing mobile phones to domestic appliances, and from music to conversations in crowded places that reach over 85 decibels (dBA). This indistinct chaos leads to an excessive and prolonged sound stimulus that is both negative for health, especially for people with hearing loss, and has a considerable social and economic impact. According to a report by the World Health Organisation/Europe[10], at least one million years of healthy life are lost every year due to noise pollution in Western Europe.

The noise to which people are most exposed in big cities is intense, such as road traffic (80 dBA), hammer drills in construction yards (105 dBA) and ambulance sirens (115 dbA).

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How do we respond to noise?

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Each of us has a different reaction to the same sound stimulus, and many variables influence our acceptance of noise. The context, for instance, has a considerable effect on the annoyance induced by noise. The GfK Eurisko survey shows that young people are more exposed to the negative consequences of excessive noise on mood than other age groups. This might be due to the lifestyles of young adults, who are more committed to work and family and, hence, are more disturbed by noise, which becomes the umpteenth stress-generating factor in daily life. Our response to noise is also influenced by the meaning it has for each of us. An airport employee will tolerate the noise of aircraft because that environment is his/her livelihood, while people living in the vicinity of an airport will consider the same sounds unbearable because they feel they cannot control them and perhaps worry that they might be affected by an aircraft accident[1]. Survey data reveal that people adapt remarkably well to noise. The number of people who say that they hardly notice or are no longer disturbed by noise is over 50% everywhere, with peaks of over 70% in the United Kingdom and the United States, where the loudest cities are located. In fact, each of us can have an adaptation or dissonance response to the environment and our living conditions[2]. This is illustrated in Table II.

Adaptation occurs when an individual is still satisfied and experiences wellbeing even when faced with objectively negative conditions; dissonance, instead, involves a feeling that quality of life is poor even in objectively positive conditions.

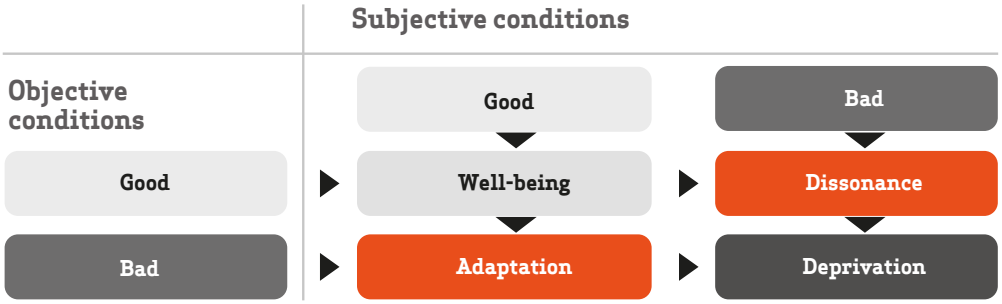

Table II
Objective and subjective conditions of quality of life[2]

The response to noise therefore differs across people. Adaptation may occur, for instance, if one is in a disco and the deafening volume becomes acceptable because it is part of the experience. Other reasons for adaptation include not being aware of the negative effects of noise or even considering noise to be an intrinsic part of city life as a consequence of cultural stimuli. In New York City and Naples, inhabitants do not expect silence. Noise is considered an intrinsic part of the local culture and, therefore, adaptation to noise is high. Conversely, there can be dissonance if the environment is quiet but our expectations are high. Urban chaos might seem intolerable after moving from the countryside. Likewise, if one has paid a large sum for a flat in a certain district, the least discomfort will be unbearable. If one has a job that requires concentration, nothing other than silence will be sustainable.

Different cultural aspects influence people's response to noise. The threshold between what is acceptable and not acceptable in terms of disturbing noises changes continuously based on individual values, experiences and habits.

All this has a considerable impact on quality of life. Noise can either improve or worsen our living conditions. In some cases the awareness that noise is negative emerges clearly, while in others low expectations or a sort of "dependence on noise" developed in urban environments or in some cultures lead to people not being disturbed by excessive noise. The difference between the objective exposure to noise and the subjective assessment is mediated by many cultural aspects that must be taken into account: the threshold between what is acceptable and what is not, changes continuously based on individual values, experiences and habits. For instance, in certain cultures road noise is perceived as a distinctive factor and an intrinsic part of belonging to the community or even as the population's mode of communication. In other frameworks, silence is deemed a sign of exclusiveness and social selection. Hence, the same level of noise can have opposite meanings, depending on the people who are exposed to it.

Besides cultural and subjective variables, other factors influence the perception of noise. Some population groups are more sensitive and, therefore, more disturbed by excessive noise exposure and more likely to develop negative effects on their health[3,4]. Moreover, non-hearing-related damage caused by noise does not show a dose-effect relation. It is not the accumulation of sound energy that causes the greatest damage, but the individual condition that determines its extent. Exposure to 85 decibels (dBA) at work can generate less stress than 65 dBA at home, when you want to relax, or 50 dBA when you are trying to fall asleep. Furthermore, exposure is more harmful in certain situations, regardless of personal adaptation skills. This is the case in schools, for instance, where noise interferes with children's learning skills[5]. If the noise is very intense and prolonged, as in the case of schools located near airports, it can impair children's reading comprehension and their long term memory[6]. Finally, even hospitals are places where noise can be highly disruptive, as patients can find it much more difficult to sleep and relax, with a subsequent negative effect on their recovery.

Finally, damage caused by noise may occur more frequently in the most susceptible people, an estimated 8-12% of the population. Unfortunately it is not yet possible to identify a priori those who are most sensitive, generally for genetic reasons. The only prevention tools are, therefore, widespread information and specialist hearing check-ups for people at risk, such as those who are exposed to noise at work. Generally, countries provide for specific legislation to protect and safeguard the hearing of people who are exposed to a high risk of acoustic trauma.

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What type of prevention?

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Modern technologies allow the development of new strategies to prevent and reduce noise in big cities.

According to the father of acoustic ecology, R. Murray Schafer, cities are "deaf" and their inhabitants are now affected by "schizophonia"[1]: surrounded by noise and unable to link sounds to their source, they are condemned to superficial listening. Today, technology enables us to accurately measure the noise levels of cities, at last helping inhabitants to become aware of the environment they live in, and to come up with noise prevention and reduction methods that can be implemented thanks to technological developments.

Many actions might be taken in the urban context to protect the population from excessive noise. Road traffic, for instance, is one of the major sources of urban noise, but mobility in cities can be changed. Promoting the widespread use of quieter electric vehicles and bicycles, by creating efficient cycle paths, can reduce the noise load of cities. Moreover, sound-absorbing asphalt can be used to build roads, tyres with reduced sound emissions could be promoted, and stricter speed limits could be enforced in cities. When applied to transport, even the "sharing economy" could help cities become quieter places. A revolution is coming with driverless cars, prototypes of which are already being produced by Google, Audi and the MIT. They might be shared by family members or local residents to meet everybody's travel requirements. A survey conducted by MIT's SMART Future Mobility team recently showed that all mobility needs of a metropolis such as Singapore could be met by just 30% of the circulating vehicles if they were driverless cars[2]. The percentage might decrease by a further 40% if passengers with a common route were to share vehicles[3].

These ideas are not wholly futuristic, and might drastically cut down noise in cities, preventing it from harming a large percentage of the population. Many noise-prevention initiatives can be undertaken by community decision makers. These include new, stricter sound limits for public premises such as pubs and nightclubs and for events such as concerts, and the creation of "silent areas" in schools, public offices and city parks to offer inhabitants effective "sound rest".

At the same time, much can be done by individuals and local organizations. Double-glazing for buildings on busy streets and "sound barriers" made from green plants on balconies and terraces reduce noise in flats. An example of eco-friendly noise-prevention architecture can be found in the home-forest that was recently planted in Turin, Italy. As well as absorbing carbon dioxide and producing oxygen, the 150 plants (trees, flowers, plants and shrubs) also act as an effective sound-absorbing barrier, insulating interiors from the harmful noise of urban traffic. It is equally important to establish volume limits for music and video players. This is an extremely useful precaution for youngsters, who usually spend several hours a day with earphones in their ears.

It is important to establish volume limits for music and video players: an extremely useful precaution for youngsters.

Besides reducing the output level of music players, hearing can be protected by using hearing protection in very noisy environments. Workers who are professionally exposed to intense noise must wear adequate ear protectors in order to isolate the hearing system from outside noise. People who enjoy listening to live music at high sound levels should purchase professional musicians' earplugs[4] that preserve natural sound quality by attenuating all frequencies equally and avoiding distortion, thus enabling them to better appreciate music while protecting their hearing. Finally, people who use music players in noisy environments, for instance in the underground, should choose earphones that cancel out external noise or fit perfectly into the ear canal, so that they no longer need to raise the volume too high to hear the music over background noise.

Workers who are professionally exposed to intense noise must wear adequate ear protectors.

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When the ear "crackles"

Noise-induced damage to the auditory system and its remediation

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Intense and prolonged exposure to noise can cause anatomical and functional damage to the ear.

If intense and prolonged, exposure to noise can cause anatomical and functional damage to the ear. Very loud noises such as explosions can perforate the tympanic membrane (eardrum). Intense but brief noises can cause acute dysfunction of the hair cells of the inner ear. Similar damage occurs, albeit gradually, in the most common situation: prolonged exposure to sounds with levels above 75-85 decibels (dBA), the threshold below which noise is deemed not to cause injury to most people. Susceptibility to noise damage varies markedly across individuals, depending on genetics, general cardio-vascular health, diet, alcohol consumption, smoking, and unknown factors. Environmental sounds characterised by low frequencies, such as the noise of cars, are generally less harmful than high-frequency sounds such as machinery noise. For a given intensity, a "pulsed" sound, such as produced by a hammer drill, is more harmful than a relatively stable one, such as a passing train.

Regardless of the type of noise that causes it, the loss initially affects hair cells and neurons tuned to frequencies between 3 and 6 kHz, and so it is revealed by a "notch" in the audiogram, usually centred close to 4 kHz, as illustrated in Figure 4. With prolonged exposure, the loss can spread to adjacent frequencies, such as 2 and 8 kHz[1,3]. Usually, hearing loss is more rapid during the first 10 years of noise exposure, but tends to stabilize between the 11th and 20th year of exposure[2], as illustrated in Figure 5.

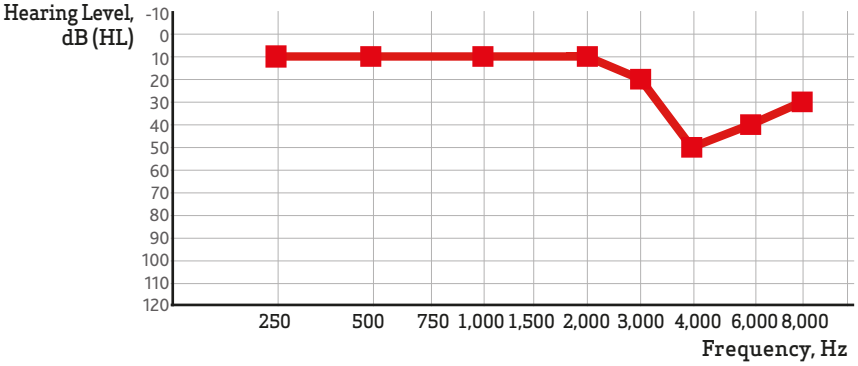

Figure 4 Audiogram typical of acoustic trauma[2]

Figure A

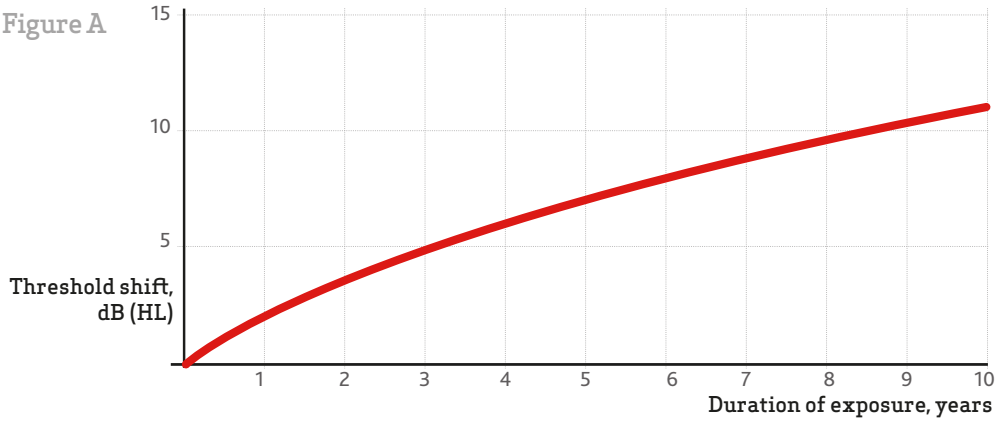

Figure B

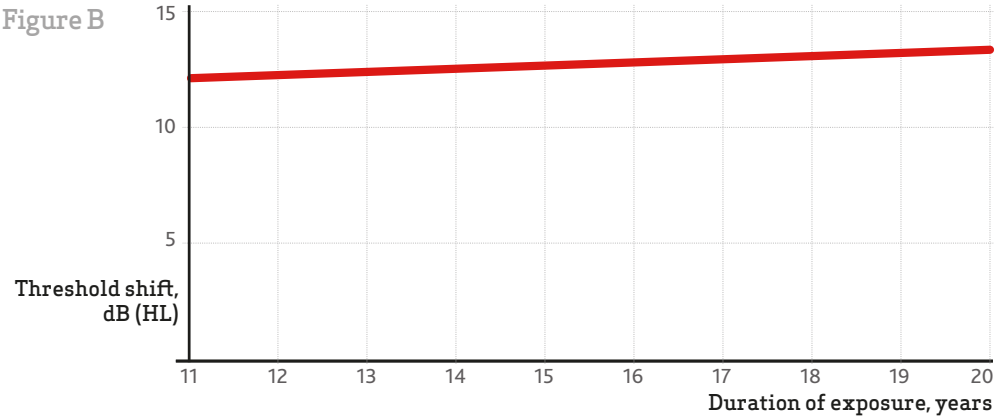

Figure 5
Time-based evolution of chronic occupational acoustic trauma at a level equivalent to 90 dBA for a person falling at the 50th percentile. Figure a) shows progress during the first 10 years of exposure, while Figure b) shows progress between the 11th and 20th year of exposure. The change is more rapid during the first 10 years of noise exposure[3]

A single exposure to intense noise can lead to temporary changes in hearing, such as a transitory increase in the threshold for detecting tones, measurable with an audiogram, distorted perception of certain sounds, and tinnitus. Until a few years ago it was believed that, since these changes were temporary, they did not reflect permanent hearing damage. However, there is recent evidence from studies with animals that noise exposures producing "temporary" hearing loss can cause degeneration of neurons in the auditory nerve[4]; this also appears to occur in humans[5]. The audiogram returns to normal because only a few neurons are required to detect a sound but many are required to discriminate sounds, especially to hear someone talking amidst background noise[6]. Hence, noise can produce damage in the auditory system that is not revealed by the audiogram, but can impair the ability to understand a conversation in a noisy environment.

There is recent evidence from studies with animals that noise exposures producing "temporary" hearing loss can cause degeneration of neurons in the auditory nerve; this also appears to occur in humans.

All this implies the need for new tests that can measure noise-induced neuronal damage and, more importantly, for a reassessment of safe noise exposures. Current exposure limits are based entirely on the audiogram, but an audiogram that returns to normal does not

necessarily mean that no nerve damage has occurred. The current safety limit, which is 85 decibels (dBA) for eight hours (with a "safe" exposure time that halves for every 3 decibel increase in sound level) should perhaps be reviewed, since neuronal damage can occur at the "safe" limit, and the threshold is widely exceeded in many situations. Music levels in nightclubs can reach 110 decibels (dBA), a situation that the current safety limits deem acceptable for less than one hour. The level at rock concerts can exceed 120 decibels (dBA)[7], a "dose" deemed dangerous with only a few seconds of exposure.

The everyday effects of acoustic trauma are not closely related to the extent of the hearing loss as measured by the audiogram. As shown in Table III, the most common problems consist of difficulty in understanding people talking in noisy environments and on TV, and in hearing the telephone or doorbell ringing[8]. Communication difficulty is the most frequent disorder, especially among elderly people who find it difficult to understand people talking in a noisy environment even when they have a normal audiogram[9]. This partly is due to age-related auditory-nerve degeneration[10], and partly due to exposure to noise[4,11] and as a consequence of cognitive deterioration[9].

Difficulty in understanding people talking in noisy environments and on TV, trouble in hearing the telephone or the doorbell ringing, embarrassment about the inability to understand are some of the most common problems a person with acoustic trauma could experience.

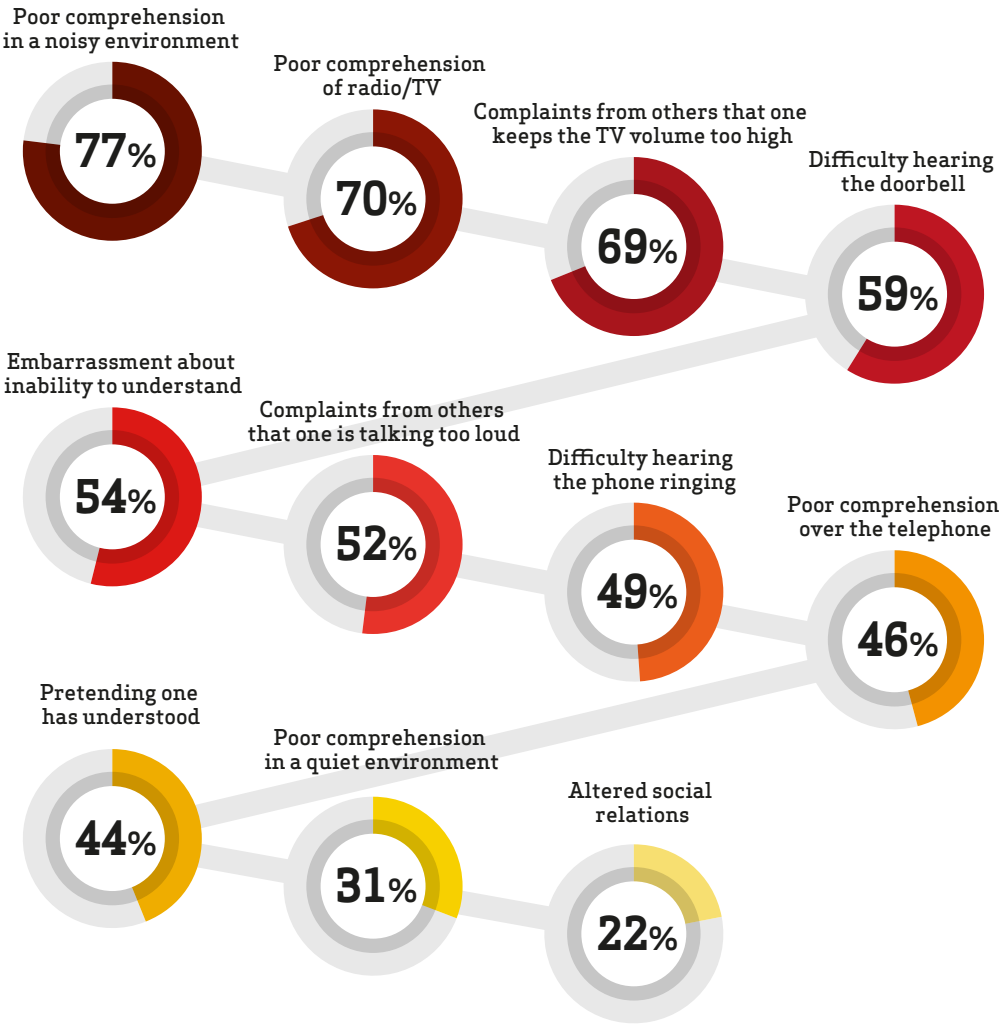

Table III
The most common symptoms experienced by people with chronic acoustic trauma and their percentage[8]

Whatever the cause might be, hearing loss and the subsequent inability to correctly follow a conversation when there is background noise can lead to social isolation[12], depression[13] and accelerated cognitive decline[14]. Hence, there is a need to educate people so that they can identify the symptoms of hearing loss and contact a doctor to confirm the diagnosis and obtain appropriate help. It is also essential to overcome the stigma associated with hearing loss, so that people who face this challenge daily can take steps to hear and live better once again. At present, only 20% of those who need hearing aids actually use them[15], often because they feel embarrassed to use them or do not wish to acknowledge the problem, even though the latest devices are barely visible and are constantly improving their performance. For instance, modern digital technology can reduce the difficulty faced by people who are less able to hear high frequencies and are disturbed by high-intensity noise, characteristics that might make sound amplification with a hearing aid quite difficult.

Only 20% of those who need hearing aids actually use them, even though the latest devices are barely visible and are constantly improving their performance.

The negative effect of perceptual distortion on comprehension can be considerably alleviated by reducing the noise in the amplified sound via the use of directional microphones and by reducing the amplification for loud sounds. However, it should be noted that hearing aids are still limited in the help provided to people with hearing loss in understanding a conversation in a noisy environment, the most difficult situation for those with noise-induced acoustic trauma. Directional microphones can be helpful in picking out the voice of a person directly in front of the user, but they are less effective for sounds coming from other directions, or when there is reverberation (in churches, for example). Directional microphones are also of limited benefit for people who wear "open-fitting" hearing aids because their ear canal remains partly open and the directional effect is therefore partly lost. Open-fitting hearing aids are often used by people with noise-induced hearing loss because they are still able to hear low frequencies naturally, without the use of hearing aids. Some people find hearing aids of great benefit, and others find them hardly useful at all. The factors underlying this individual variability are poorly understood, and research is needed to establish the factors influencing the benefit from hearing aids and to determine how to process sounds to produce the greatest benefit for a specific individual.

Research suggests that one measure, which is used in a few clinics around the world, may have the ability to predict hearing aid success. This measure is known as the acceptable noise level (ANL). The ANL test determines a listener's willingness to accept background noise while following the words of a story, and it is relatively quick to administer. It is important to note that the ANL test is not a test of speech understanding/intelligibility nor a measure of tolerance[17]. Some research suggests that individuals who can accept large amounts of background noise while following a conversation may be successful hearing aid users[17]. While research at this point is controversial into the predictive value of ANL[17,18], it seems that ANL may give the hearing health care provider some indication of the likelihood of acceptance of hearing aids, subsequently aiding in the programing of hearing aids and/or rehabilitation guidance for individuals seeking hearing aids.

Many assistive listening devices are available to meet the needs of those with hearing loss, such as mini-microphones that can be placed near the mouth of the person it is desired to hear. These devices amplify the voice and transmit it to the hearing aids through a wireless system. Today there are reasonable ways of alleviating the vast majority of types of hearing loss, thanks to the crucial contribution and professional expertise of hearing aid specialists. These professionals can customise devices that are more and more similar to wearable mini-computers that are designed to be connected wirelessly to devices such as smartphones, TVs and smartwatches. These devices can also send signals to hearing aids, to improve communication, the user's wellbeing and quality of life. Systems that transmit acoustic signals through magnetic induction, Bluetooth or Wi-Fi can be used in closed environments such as classrooms, cinemas, theatres and churches, as they reduce background noise. Widespread use of these technological devices can considerably improve the quality of life for people with hearing aids and reduce their negative psychological impact – still a primary cause of people failing to use hearing aids today.

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FOCUS:

Tinnitus and hyperacusis

Two important "side-effects" of noise

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As well as producing hearing loss, excessive noise is associated with two specific hearing conditions that often manifest together, namely tinnitus and hyperacusis. Tinnitus is considered a "phantom auditory perception" of sounds not generated by external sources[1,2] and is experienced at least once in a lifetime by 10-25% of the population and persists in about 4% of cases. Hyperacusis is an intolerance of low or moderate level external sounds that are normally tolerated by other people. It occurs in about 10% of the population and peaks at 17% in young people and adolescents[3]. This condition can cause sufferers to "flee" from the sound environment and can be associated with over-protective attitudes, phonophobia (fear of sound), misophonia (dislike of a specific sound) and psychopathological conditions. A summary of the possible effects of noise exposure on hearing is provided in Table IV.

Noise exposure can create the conditions for the appearance of tinnitus and hyperacusis.

Both disorders are more common in people with hearing loss of all types[4], but noise-related hearing loss seems to be a major cause of tinnitus[5,6,7,8], even for children[9,10]. By contrast, the correlation between hyperacusis and acoustic trauma, though very frequent, seems to be less univocal[11]. Tinnitus and hyperacusis are very often associated and may develop in sequence or in parallel. 40% of people with tinnitus also complain about hyperacusis, and 80% of those with hyperacusis also have tinnitus[12]. Tinnitus is experienced in the absence of noise, and silence is therefore seen as a negative factor, while moderately noisy environments are considered a "refuge", since, for some people, noise can "mask" the tinnitus and therefore conceal the symptom. In the case of hyperacusis, even a slight noise may be deemed "inhospitable" or "aggressive", and silence thus is a haven for sufferers.

Tinnitus is underpinned by many mechanisms but it is estimated that at least half of cases are audiogenic - i.e. caused by deafferentation or sensory hearing deprivation[13]. The "drop" in the signal being sent to the brain caused, for instance, by noise-induced hearing loss leads to an increase in the "gain" or "amplification" applied by more central mechanisms, leading to changes in neural activity (causing, for instance, an increase in spontaneous electrical activity in the brainstem or auditory cortex). In the course of time, such changes become increasingly "central", and less dependent on peripheral hearing organs[14]. The frequency of symptoms and the success or failure of treatment depend on the degree and type of short, medium and long-term neuroplastic processes.

There is less information about the causes of hyperacusis, although more and more studies are being carried out in this area due to its psychological and social repercussions and its growing incidence, especially in young people. Hyperacusis is closely related to the presence of noise. In practice, it can neither manifest nor evolve where there is silence; hence, the trigger must be sought in neurological, chemical and electrophysiological changes caused by noise, along with biological and psychological mechanisms with a predisposing and propelling effect. Hyperacusis certainly is not only due to damage to the peripheral auditory system, though it is often triggered by over-exposure to noise. One theory is that serotonin metabolism may be altered[15]. Based on data from studies on animals[16], even moderate early hearing deficiencies caused by recurrent otitis media, for example, can be a risk factor for subsequent hyperacusis since they may generate abnormal noise perception. The disorder is often associated with autism, being found in 18% of cases[17], and it is associated with other sensory anomalies, such as intolerance to light and smell[18]. Hyperacusis can be detected in children under the age of eight since some behavioural patterns in response to moderately intense noise are unmistakeable (placing the hands over the ears, crying, looking frightened, and running away). As for adults, it is often triggered only by specific sounds initially, but can progress to include other types of stimuli (from the sound of certain toys to some or many voices).

Noise can also lead to annoyance, a multifactorial condition found in populations exposed to noise levels that are not harmful to the auditory system but still lead to psychological, biological and social alterations.

Noise and tinnitus

Tinnitus occurring after noise exposure can be reversible if the exposure is moderate in duration and/or severity, but the tinnitus can be persistent in cases of over-exposure. Peripheral hearing "distress" causes a reduction in sensory input, and this may trigger tinnitus. There is also an instant, direct association between noise and the worsening of symptoms but the connection seems to go further. Noise causes what is known as "annoyance," a multifactorial condition found in populations exposed to noise levels that are not harmful to the auditory system but still lead to psychological, biological and social alterations. Annoyance occurs in airports, industrial settings and construction yards where there is heavy traffic. It is the cause and consequence of an "over-surveillance" condition and is associated with sleep disorders, which are also associated with tinnitus. Studies are therefore being carried out on the complex relationship between noise-related tinnitus, insomnia and over-surveillance, and the correlations between cerebral activation, sympathetic system hyperactivity and tinnitus are becoming evident[19].

Noise and hyperacusis

Noise exposure and hyperacusis are linked, both because noise itself is necessary for symptoms to manifest and because it triggers over-surveillance, which can worsen the symptoms and make them chronic. There is therefore considerable affinity between annoyance and hyperacusis, which might be an expression of annoyance until it becomes a more advanced, complex condition such as phonophobia or misophonia.

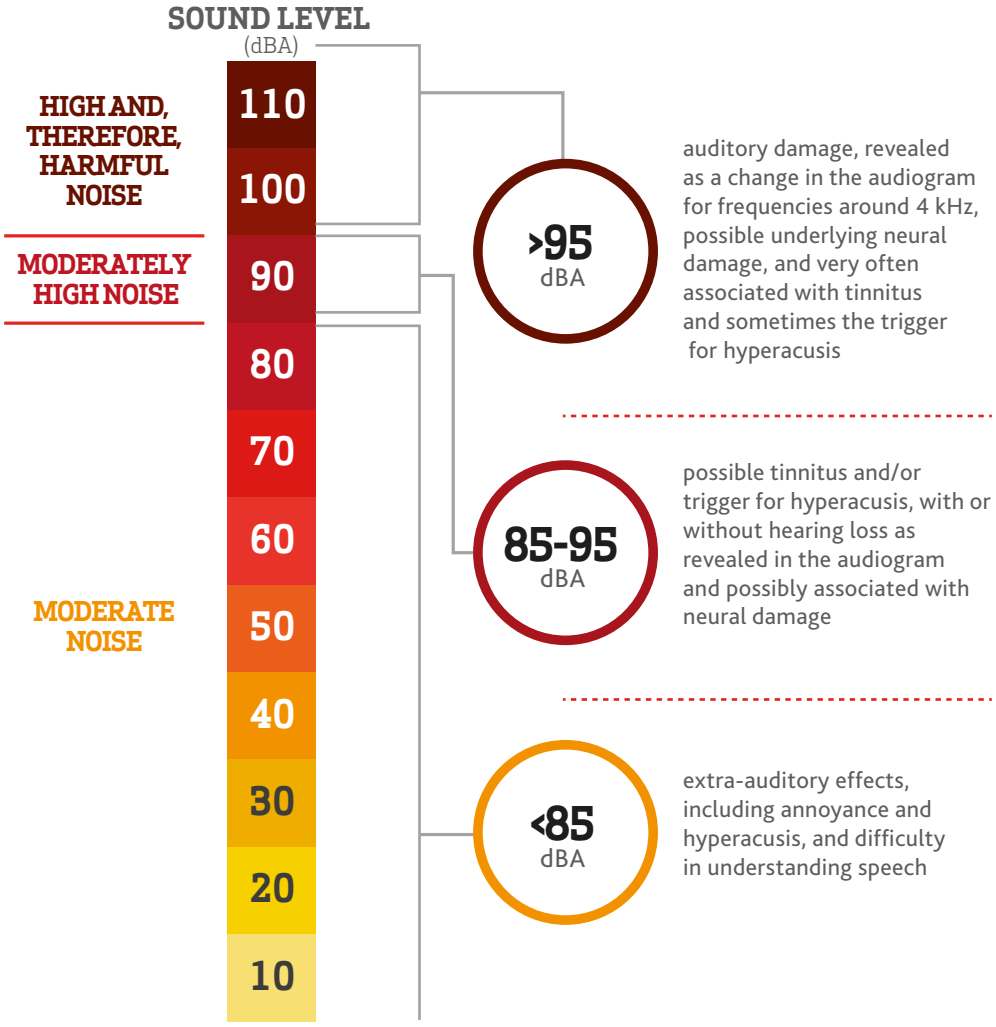
When noise triggers hearing loss, tinnitus and hyperacusis

Over-exposure to noise sometimes causes hearing damage, tinnitus and hyperacusis at the same time. This can occur, for instance, following a work-related accident, when occupational safety standards are not properly observed, or in the case of environmental accidents, war or military events. But it may also result from an excessive use of music players with earphones or earpieces, by listening to loud music in the car, attending pop/rock concerts, at nightclubs or as a result of arts and musical activities[7]. In Italy, 12% of the population aged 12-65 is regularly involved in a musical activity associated with exposure levels that potentially can cause hearing damage and a combined disorder. The combined onset of hearing loss, tinnitus and hyperacusis can lead to long absences from work, with repercussions for emotional and psychological wellbeing and a negative impact on the course of tinnitus and hyperacusis themselves. Sound perception can be muffled after one or more episodes of over-exposure to noise, as a result of a tensor tympani muscle disorder[20]. Such a symptom can arise after acoustic shock and is often associated with hyperacusis, the most serious and disabling problem for many people[20].

Prevention and treatment

While the likelihood of developing tinnitus can be reduced by avoiding exposure to excessive noise, it is harder to define an effective "rule" for preventing hyperacusis. The onset is often unpredictable and the noise levels involved are quite different to those that trigger tinnitus or hearing loss. However, much can be done to ensure that symptoms are recognised early and diagnosed correctly, thereby reducing both discomfort and possible complications. In the case of tinnitus, for instance, it is important to monitor people who are exposed to noise[13]. Generally, treatment of tinnitus is centred on desensitisation strategies designed to raise tolerance levels and reduce the over-activity of nerve structures. If tinnitus is associated with hearing loss and hearing aids are required, the person is usually given an "open-fitting" solution, to avoid the occlusion effect, or, even better, a combined solution that can also generate a "therapeutic" noise for sound therapy when required.

Treatment for hyperacusis is more complex. Early symptoms are not hard to detect, such as adopting over-protective measures (e.g. always keeping ear plugs within reach), gradually avoiding environments perceived as risky even if they are not, reactions of fear and pain during exposure to low intensity noise (running water, paper crushed into a ball, and so on), a sudden change in lifestyle, and a tendency to avoid social interaction. These are all clear signs, and they often appear in childhood. Early diagnosis is essential because the disorder often evolves rapidly towards psychological and social unease. There is, unfortunately, still no cure, but intervention strategies include desensitisation treatment based on "sound habituation therapy" and cognitive-behavioural therapy that uses low-dose noise. The aim is for sufferers to gradually learn techniques that allow them to tolerate environmental noise. The use of hearing aids, which must only be fitted after adequate and often long periods of rehabilitation, should be avoided in case of associated hearing loss.



NOTE: noise can have a negative effect, prolonging or worsening existing tinnitus and/or hyperacusis

Table IV
Possible effects of noise exposure

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"Let's make noise" to build awareness

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Few people know about "noise sickness". The GfK Eurisko survey data reveal that only one out of two people are aware that hearing loss can be caused by frequent and prolonged exposure to intense noise. In countries such as Italy, Portugal and New Zealand, awareness is as high as 60%, but little is known about noise-induced damage in most countries; younger generations seem to be less aware of the risks, although they are potentially more exposed to them. The potential consequences of noise are considerably underestimated in Germany, The Netherlands, the United Kingdom and the United States. 54% of people know that excessive noise can generate stress, 49% are aware that it can disturb sleep, 47% know that it causes irritability, and 45% are aware that it can reduce concentration. However, barely one fifth of people know that it is associated with a higher risk of anxiety, and less than one in ten associate exposure to excessive noise with memory disorders and a high risk of cardiovascular diseases, a connection that has only recently emerged. Only 28% of the population think they have sufficient information about noise-induced damage, with peaks of over 40% in Italy and Portugal compared to a mere 20% of properly informed people in The Netherlands and the United Kingdom.

Only one out of two people are aware of the link between noise, moods and sleep. Half of the population ignores its negative consequences on hearing.

The lack of awareness is a cause of inadequate prevention of noise-induced damage, both personal and general. The first objective must therefore be to improve overall awareness of the risks of exposure to noise and the type of sounds that can impair hearing. It is equally important to give people detailed information on the symptoms of noise-induced acoustic trauma, which despite having transitory symptoms, can cause permanent nerve injury and must therefore be considered a warning sign telling us to protect ourselves adequately. Advice should be given about suitable measures, such as shutting out external noise with acoustic barriers such as double-glazing, noise-cancelling earphones and wearing "earplugs for musicians" when attending loud concerts or nightclubs.

Greater public awareness of the risks of noise exposure should also lead to policies designed to protect citizens, ranging from speed limits on roads at certain hours of the day and stricter regulations for public premises. The sound level allowed for concerts, nightclubs and pubs should be regulated, and it is vital to reassess safe exposure levels:

recent studies suggest that damage can be caused by lower noise levels than those deemed safe today.

To improve diagnosis and subsequently treat noise-induced hearing loss, we also need tests that can recognise the underlying nerve damage in order to ensure prompt intervention. It is also essential to promote awareness of the effectiveness and ease of use of hearing aids, since they are still ignored by many people.

Moreover, reducing the stigma associated with hearing aids would encourage more people who might benefit from them to understand their possible advantages and use them confidently. In the near future these increasingly customisable devices will be even closer to meeting each person's specific needs. It may also be possible to estimate the individual outcome of using hearing aids, providing the people who need greater assistance with the care they need and ensuring that the results are as successful as possible.

"Coping with noise" project coordination

Edelman

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