



# NON-AUDITORY EFFECTS OF NOISY UNCOMFORTABLE WORKPLACES

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## ABSTRACT

The classical approach to occupational health and safety management and control, based on measuring and reducing risk levels does not seem to be effective in improving quality of workplaces and quality of workers' life. It should be integrated with models and actions that consider objective comfort variables and the subjective perception of wellbeing during worktime. Almost everywhere, legislative and regulatory scenarios show a poor or null consideration of the non-auditory effects produced by exposure to noise and poor acoustic quality of workplaces. In this paper the acoustic quality variables are considered as components of the global comfort design of workplaces with special attention to reducing the risk of non-auditory effects on workers' health. Some results of a recently completed Italian inter-universities project on non-auditory effects of noise exposure in workplaces, with special attention to schools, are shown.

Among them, a collection of guidelines referred to experiences and methods aimed at understanding the correlation between acoustic quality of and various physiological and psychological pathologies, included vocal effort, perceptive-cognitive performance and more.

**Keywords:** *noise, non-auditory, effects, comfort*

## 1. INTRODUCTION

Among the emerging physical risks in the workplace connected to comfort there are the non-hearing effects of exposure to noise.

Article 32 of the Constitution of the Italian Republic, as many other national and international directives, laws and regulations, recognizes the protection of health as a

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fundamental right of the individual and in the interest of the community. The protection of health and the pursuit of well-being are the principles that should guide anyone involved at various levels in the design of public and private spaces, open and built environments, places and scenarios intended for the permanence of people, including work environments.

The presence of noise in the workplace is not only a possible source of pathologies of the hearing system but also potentially responsible for damage to other systems and, more generally, for psychological conditions of stress and perceived discomfort.

A review published in the Lancet in 2014 [1] shows how many disability-adjusted life years (DALYs), depend on noise exposure.

The WHO defines various noise levels, lower than 80 dB, the generally considered threshold of risk for which significant non-auditory effects of noise exposure can generate pathologies: From 30 to 50 dB noise can have harmful effects for vulnerable groups (children and the elderly), while beyond 50 dB the danger to public health increases and the main harmful effects are sleep disturbances, annoyance, cardiovascular diseases, cognitive problems. [2].

## 2. THE NON AUDITORY EFFECTS OF NOISE EXPOSURE

The context for studying auditory and non-auditory effects of noise is the soundscape, which is disturbed, made unpleasant, uncomfortable. With this approach noise may become a source of discomfort, stress, damage to health, other types of damage [3]

### 2.1 A synthetic review

The categories that represent the effects of noise on health have been studied and defined at both scientific and applicative level, in order to include, together with the pathologies that cause functional problems to the hearing system, also problems and pathologies resulting from multisensory perception of the discomfort.

These perceptual aspects fall into the categories of noise disturbance and annoyance, a parameter defined by the World Health Organization (WHO) whose most recent guidelines on environmental noise have been published by the Regional Office for Europe in October 2018 [2]. This important WHO report substantiates, through evidence based on research and literature data, the importance of noise exposure and related disturbance for the population as a public health problem, not only in terms of hearing damage. In fact, there are other physiological evidences of damage to health deriving from exposure to noise, other than hearing loss and tinnitus: effects on cardiac function deriving from the increase in heart rate and blood pressure, increase in respiratory frequency, disorders of the organ of balance and even the digestive system. And, of course, physiological effects related to vocal effort, widespread among those who work in environments intended for speech and listening with high levels of background noise.

From the literature commenting on the WHO guidelines, we get important indications on the typical reaction and adaptation mechanisms of the human body that provoke non-auditory disease, directly and indirectly.

The direct effects are structural damage to the cochlea, hyperactivity of the central auditory nuclei, involvement of areas of the central auditory system and activation of the alarm system and the hypothalamic-pituitary-adrenal axis. Exposure to certain types and amounts of acoustic emissions can stimulate hyperactivity in the central auditory system. Long-term activation of the alarm system can cause hormonal balance disturbances and morphological and functional changes in the brain, potentially underlying the mechanism for subsequent noise-induced cognitive impairment and neuro-behavioral manifestations. The WHO guidelines speak explicitly of the possible direct consequences of exposure to noise on pregnancy and birth and of a potential onset of metabolic diseases such as diabetes and obesity.

Indirectly, noise acts by interfering with the ability to hear sounds clearly, in particular by reducing the intelligibility of speech due to the excessive permanence of the reverberated components or by acting with distracting actions that make it difficult to understand messages and unpleasant to listen to. Furthermore, the greater interpretation effort required to compensate for this discomfort causes tension and psychological fatigue in exposed subjects, leading to unconscious behavioral modifications.

Briefly reporting what can be derived from wide and consolidated literature, it can be said that the main non-auditory physiological effects are generated by the interference of noise with mental activities that require attention and concentration and generate the onset of physiological and psycho-behavioral problems.

The importance of non-auditory effects is even more evident if they are considered from the point of view of health promotion, i.e. the discipline that deals with the correlations between occupational risks and lifestyle habits.

By a more systematic review, it is possible to derive a catalogue of non-auditory effects, distinguishing five categories.

## 2.2 Physiological effects

The physiological non-auditory effects of noise exposure derive by the interference of noise with attention capacity, memory and ability to deal with complex problems.

Among the adaptation strategies are the increase in blood pressure, high blood levels of stress-related hormones, weakened immune defenses, gastrointestinal problems and, cardiovascular problems with hypertension and increased risk of heart attack.

There is extensive and documented evidence in the literature of the relationship between exposure to noise and the onset of ischemic heart disease and hypertension, starting from daily exposure levels between 65 and 70 dB(A) of LAeq [1].

## 2.3 Acute effects

The non-auditory effects of noise exposure can produce severe disease through slow mechanisms, which manifest themselves after months or years.

However, there are also acute non-auditory effects from exposure to noise which can be very serious, even fatal. The study of acute effects deserves great attention and new and widespread epidemiological and clinical research is desirable.

Particular acute effects, which are the responsibility of the emergency departments, should therefore also be included in the overview of the deaf effects of noise exposure. Although only serious tympanic lesions and inner ear structures in the event of sound wave traumas have historically been considered in this area, in recent years some studies have begun to systematically address the contexts that gave rise to exposure risks, complicated by acute events: these are mainly airports, city traffic, some manufacturing workplaces, shipbuilding [4].

## 2.4 Effects on communication

The main effects on communication are the interference of noise with the ability to concentrate and memory, as well as on the level of intelligibility of sounds (the speech of a speaker, warning or alarm signals). In environments characterized by high levels of background noise, the need to be understood raises the voice, consequently increasing the background noise (Lombard effect) and can induce aggressive behavior as an extreme effect of progression. In working environments intended for speech and listening, or where clear and timely receipt of audible warnings is important, the equivalent level LAeq of background noise should be at least 10 dB(A) lower than the speaker's voice level or of the signal to be heard [5].

In workplaces the unnecessary noise can be source of accident; the risk assessment must consider possible interactions between noise and warning signals: high background noise levels could cause signal audibility problems and, consequently, constitute a potential danger for the safety of workers, to be considered in the assessment of risks.

Another potential non-auditory effect to be taken into consideration in the evaluation process of exposure to noise is that linked to the evaluation of the effectiveness of hearing protectors: the potential phenomenon of overprotection, in fact, concerns those possible effects on the safety of workers deriving from an excessive isolation caused by personal hearing protectors that can mask fundamental signals such as warnings, alarms, or even communications among colleagues.

## 2.5 Effects on learning

The category of effects on learning includes deficits in the ability to concentrate and psycho-physical stress, as well as negative effects on reading and speaking skills [6].

## 2.6 Effects on learning

This category include all aspects of the correlation between noise exposure and sleep disturbances: difficulty falling asleep, reduced deep sleep phase, increased awakenings and adverse effects after awakening, such as fatigue and impaired performance.

## 2.7 Psychological and behavioral effects.

This category concerns the aspects and the degeneration of annoyance and discomfort feelings caused by noise: loud noise induces stress and increases the possibility of

aggressive behavior on predisposed subjects and reduction of instinctive reflexes in response to dangerous situations, with potential repercussions in terms of safety.

In many working environments, the combination of these effects decisively reduces safety and, in the case of service operators, also the quality of services.

In the health sector, for example, the effects on communication, on learning, on rest and sleep, on perceived discomfort in general, can have repercussions on the operational effectiveness of healthcare workers, representing a multifactorial complex that can increase the clinical risk, the worsening of health worker/patient relationships, increased risk of burn-out, especially in difficult sectors such as Emergency Departments, Intensive Care Units, Operating Theaters [7].

## 3. PROJECT BRIC AND GUIDELINES

Within the scope of the results and products of the Bric 2019-ID 14 project, funded by INAIL, the Italian National institute for insurance against accidents at work, an important position is occupied by the preparation of new guidelines for the prevention of extra-auditory effects.

Following the project implementation a collection of was created.

The first part contain a general presentation and introduction to the problem of non-auditory risks deriving from exposure to noise: it contains the definition of annoyance, as introduced by the WHO and its declination in the field of occupational noise and with hints of acoustic metrology aimed at ascertaining the levels of annoyance in the workplace.

The evidence of correlation between noise and effects on health is then explored, through a review work including the collection and cataloging of the evidence present in the scientific literature as produced by research on animals and humans and in the jurisprudence relating to disturbing effects in civil and labor law.

Then acoustic sources and complex noise scenarios that cause extra-auditory pathologies are presented together with an examination of the consequent damages to health having physiological, psychological, psychiatric and neurobehavioral nature.

The second part of the guidelines is dedicated to the first application of the research: classrooms and other school environments.

Starting from an accurate acoustic analysis of the sample school complexes, the methodology for selecting the

spaces and carrying out the surveys is described, considering the measurement and evaluation of the acoustic climate and the other characteristics that determine the acoustic quality of the environments intended for study and permanence of students and teachers. Measurements of the acoustic climate outside buildings and measurements of occupied and unoccupied classrooms of the main parameters of architectural acoustics, associated with the geometric characteristics and intended use of the classrooms and other environments investigated in schools. Other campaigns were added to these with measures and evaluations of the teachers' vocal effort and finally, to evaluate the perception of noise disturbance as well as the impact on psycho-behavioral reactions, tests were carried out and questionnaires were administered on verbal comprehension and subjective perception of the sound environment in different environments.

The third part of the guidelines is dedicated to the description of the strategies and possible solutions to be adopted for designing new work environments and acoustically correcting existing ones in order to reduce the risk of possible non-auditory effects on workers.

An attempt has been made to define a first draft of possible strategies and methods for assessing the risk of extra-auditory effects which could be the basis for a regulatory update, going to compensate for the lack of references already mentioned, integrating the existing legislative provisions, referring mainly, if not exclusively, to hearing risk assessment.

The correlations and cause-effect relationships between acoustic quality and perceptive-cognitive performance, between acoustic quality and vocal effort, between acoustic quality and other pathologies of a physiological nature are considered, always with a view to providing indications for the acoustic design of new educational spaces and acoustic correction of existing teaching spaces.

In the last part of the guidelines a series of non-technical interventions for organizational and procedural improvement are considered to reduce exposure to noise, also considering the health promotion aspects that can be integrated into strategies and methods for noise risk prevention.

The final chapters of the Guidelines contain a collection of design indications for the design and acoustic correction of acoustically comfortable educational and recreational spaces, with design features aimed at improving cognitive performance and preventing physiological damage and behavioral disorders.

#### 4. CONCLUSIONS

There is a conceptual evolution in assessing and planning the acoustic quality of work environments and activities. New approaches to noise assessment in workplaces, in terms of acoustic damage, noise disturbance, acoustic discomfort, are emerging

Noise is considered as a parameter of global discomfort and perceived discomfort in the permanence in working environments, in carrying out work activities, in the worker's living environments and in the performance of extra-work activities that can affect his acoustic health (bad acoustic habits).

There is a new consideration, also in terms of compensation for both auditory and non-auditory (physiological, psycho-behavioral) effects of exposure to noise and a new consideration of the acoustic quality of spaces for speech intelligibility, correct sizing of the safety and alarm signals, reduction of background noise and unnecessary sounds

Noise produces negative impacts on people's health and well-being through auditory and extra-auditory pathological effects, which affect the hearing organ and other organs and systems. For this reason, it is right and necessary that prevention policies consider, or rather reconsider, the non-auditory effects of noise among the emerging physical risks.

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