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EVALUATING THE LINK BETWEEN ACOUSTIC CLIMATE IN WORKPLACES AND EXTRA-AUDITORY DISORDERS: THE CASE OF SCHOOL ENVIRONMENTS

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ABSTRACT

Extra-auditory disorders represent an emerging environmental and occupational issue, which negatively affects health and quality of life and work. School environments are complex working contexts, suitable for studying the link between acoustic climate and extra-auditory pathologies. The acoustic climate in schools can be compromised by noise coming from both internal (classrooms, corridors, gymnasium) and external sources. Exposure to noise can cause distraction and reduce the e effectiveness of communication, thus compromising learning. It can cause annoyance, fatigue, increased stress acting on the hypothalamic-pituitary- adrenal axis and it can indirectly cause phonatory impairment of teachers. Assessing the acoustic climate and its link with the extra-auditory effects of noise require to consider individual conditions of susceptibility such as individual sensitivity to noise, gender and age in correlation to the task performed. A workplace risk assessment including extra-auditory effects of noise exposure is a first step towards safer and quieter school environments: it should identify the disturbing sources, consider the characteristics of the workforce and plan improvement interventions. The Occupational Physician, as the global workplace health consultant, play a key role by collaborating in risk assessment, identifying at-risk working population, carrying out health surveillance, intercepting disturbs in their early stage, and informing and training workers.
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Keywords: *extra-auditory effects of noise, school environments, occupational medicine, acoustic climate.*

1. INTRODUCTION

Noise has been recognized for many decades as a major environmental and occupational problem, negatively affecting health, quality of life and work, and general well-being. In Europe, around 40% of the population is exposed during the day to road traffic noise at levels above 55 dB (A), 20% is exposed to levels above 65 dB(A) and more than 30% is exposed at levels above 55 dB(A) during the night. In the workplace, exposure to noise is one of the most common risks; it is estimated that around 20% of the European population is exposed to noise risk and the percentage is higher in the countries of emerging economies [1]. The noise parameter that most correlates with the probability of developing both auditory and extra-auditory disorders is sound intensity, measured as a sound pressure level in dB. However, in recent years, other characteristics of the sound have also proved to be important for evaluating the link between the acoustic climate and any disturbances in the exposed. The first effect of exposure to noise in the workplace, in environments where the acoustic pressure is higher than 85 dB Lex (8h), is noise-induced hearing loss which represents the clinical manifestation of progressive and irreversible damage to the cochlear hair cells. Individual susceptibility, such as the male gender, chronic pathologies, and other occupational risks such as exposure to vibration or ototoxic substances can lead to hypoacusic phenomena even for sound pressure values lower than 85 dB. Along with hearing loss, another hearing disorder from exposure to noise is tinnitus, or the auditory perception of ringing, hissing or rumbling. Impulsive noise environments substantially increase the risk of developing tinnitus, which is sometimes

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the first sign of noise-induced hearing damage. However, exposure to noise, both professional and environmental, can also cause extra-hearing effects. These effects can occur for sound pressure levels lower than the maximum ones determined by legislative standards and therefore also in working environments with noise levels considered at low risk, such as schools. In this context, especially when referring to extra-auditory disorders of a neurobehavioral nature, therefore with a relevant individual subjectivity component, in addition to sound pressure levels, other characteristics of noise can also contribute to the definition of "dangerous noise". Characteristics such as frequency, duration of exposure and interruptions of exposure may be relevant to the effects of noise on human well-being. For example, irregular or pulsating noises can be more annoying than constant noise [2-4].

2. SCHOOL ENVIRONMENTS AND NOISE

School environments represent one of the most emblematic and most complex working contexts for studying the link between acoustic climate and non-hearing pathologies, both for workers and students [5]. In school settings, exposure to noise can cause distraction or difficulty in interactions between people, reducing the effectiveness of communication. In fact, good verbal communication requires that the level of speech perceived by the ear is at least 10 dB higher than that of the surrounding noise. In this sense, even from the case studies developed for the BRIC INAIL ID 14 project, it emerges how much the noises inside the classrooms are considered, from the subjective point of view of teachers and pupils, as extremely disturbing. The acoustic climate inside the classrooms is compromised both by the noise inside the classroom itself and by the noise coming from the corridor and neighboring classrooms, and causes relevant subjective symptoms, especially when the acoustic insulation between two rooms is not sufficient. Particularly intense noises such as the dragging of desks and chairs are annoying for most users. This disturbed acoustic climate can cause various problems in the learning sphere, as noise limits, both directly and through the reduction of verbal comprehension, the possibility for pupils to follow the teacher and to concentrate on teaching activities. Frequent disturbances are loss of concentration and headache, also mediated by the difficulty of hearing the teacher correctly. Noise in classrooms, whether caused by external or internal sources, can affect performance, reading and memory skills, following the teacher and working with numbers, at sound pressure levels above 58dB. In this sense, the soundproofing between classroom/classroom and classroom/corridor represents a fundamental aspect to reduce the probability of the onset of extra-auditory pathologies caused by noise. It should be taken into consideration that the noises generated inside the classroom itself (classmates talking, objects falling, furniture moving) are the ones that generate the most annoyance, in some cases exceeding levels of 80dB for interactive activities. Some data show that sound pressure levels can even exceed 90 dB, especially in corridors or during some specific activities. Above the threshold of 80 dB, the possibility of the appearance of auditory and extra-auditory effects of noise becomes even greater. For hypersensitive subjects, a temporary increase in hearing threshold, tinnitus and increased sensitivity to noise can be observed, for example. However, the damage that occurs most frequently is the loss of concentration and fatigue. Emotional reactions such as anger, oppositional behaviors, greater ease of crying are also to be related to exposure to noise. If the sound pressure levels are higher (with a threshold between 60 and 70dB depending on the authors), an increase in blood pressure and cortisol values can be determined, even in school-age children. Symptoms such as tiredness and headache are to be considered as a response to stress. It should be taken into consideration that children are more susceptible to exposure to noise for a variety of reasons, often they cannot escape exposure, while adults can do so, nor do they have the awareness or tools to understand the emergence of any disturbances. Furthermore, children have not developed coping mechanisms and cannot always change their situation. These factors combine to generate or trigger a wide range of negative effects that can also affect neurocognitive development and learning abilities [6].

3. THE LINK BETWEEN ACOUTISTIC CLIMATE AND NEUROBEHAVIORAL ALTERATIONS

In assessing the acoustic climate and its link with the extra-auditory effects of noise, individual characteristics must be taken into account, including gender, age and individual sensitivity to noise. Among school workers it is not infrequent to find a marked sensitivity to noise, which can exacerbate somatic symptoms following exposure. The acoustic climate, therefore, acts primarily on two aspects: the need for vocal effort and the auditory and extra-auditory effects of noise. The vocal effort of teachers, which can lead to pathologies of the vocal cords in the long term, can be correlated with the acoustic comfort and with the reverberation characteristics of the school structures. Frequent disturbances in this sense can be hoarseness, aphonia and dysphonia, but also physical and mental fatigue.

Furthermore, the noise of the environments reduces the perceptive/cognitive performances also for adults. Both directly and indirectly through neurobehavioral reactions, noise in school environments can cause significant stress reactions in school operators, especially teachers. Noise in the workplace, even when it does not reach a level that requires interventions to prevent hearing loss, can be a cause of stress, although its impact is decisive only in conjunction with other factors. How noise affects workers' perceived stress levels depends on a number of factors such as the nature of the noise, including its volume, pitch and predictability, the complexity of the task being performed (for example, other people speaking may constitute a stress factor when the operation in progress requires extreme concentration), the occupation of the worker and the characteristics and conditions of the worker himself, such as tiredness and physical and cognitive exhaustion. Teachers, carrying out a complex task that requires constant attention and concentration, in an environment where noise is unpredictable, non-constant and characterized by different tones and frequencies, are in this sense at a high risk for the development of stress. Chronic stress, in addition to having repercussions on the psychological level and on work performance, can determine pathophysiological responses that generate or increase cardiovascular risk factors, including the increase in blood sugar, lipids, blood pressure, viscosity of blood and the stimulation of blood clotting. Endothelial (vascular) dysfunction is also caused by chronic stress reactions involving activation of the autonomic nervous system, increased levels of circulating cortisol induced by oxidative stress and consequent stimulation of prothrombotic pathways and vascular inflammation. Noise exposure has been associated with increased incidences of coronary heart disease, stroke and arterial hypertension, and similar mechanisms can lead to an increased risk of obesity and diabetes, with exposure to sound pressure levels above 60dB. Exposure to noisy acoustic climates can also determine states of anxiety, depression, through pathways involving alarm systems, catecholamines and cortisol. The sources of noise that have the greatest influence on the acoustic climate and which are perceived as disturbing by both teachers and pupils are the activities of the students in the classroom and in the surrounding spaces (classrooms and corridors). Given the importance of individual susceptibility, the acoustic climate from internal building noise sources can be linked to various physiological disturbances. The age of the students and the activities carried out influence the acoustic climate and therefore any disturbances. The noise coming from external sources is not perceived as significant since the noise generated by internal sources in the classroom often makes the disturbance caused by external sources negligible, or at least little perceived, during regular teaching activities. However, considering the literature evidence, which suggests that noise pollution from vehicular and air traffic or from industrial areas is able to determine or aggravate important pathologies such as cardiovascular diseases, diabetes, sleep disturbances and annoyance, the acoustic climate inside schools, noise attributable to sources outside the building should be excluded as much as possible by evaluating the acoustic performance of the facade, especially when the school building is located in particularly busy areas (motorway junctions, railway stations, industrial areas) [7]. In most cases, the noise coming from outside is not considered disturbing, but this does not mean that it cannot contribute to triggering stress mechanisms that can result in cardiovascular or endocrine diseases. However, there remains a proportion of individuals - probably more sensitive to noise - who suffer the effects of noise caused by external sources. In school buildings located near transport infrastructures, the percentage of those who feel disturbed by external acoustic sources is very high. Motor vehicle traffic is the most disturbing: traffic noise seems to have a small but tangible independent effect on the risk of stroke, when it exceeds the threshold of 70 dB. Even the activities that take place in the external areas of the schools can contribute to determining neurobehavioral disorders, for this reason an organization of the activities that takes this data into account can be an important measure to reduce noise-related disorders. The first complaints reported are fatigue, loss of concentration, headache and neurobehavioral disorders such as increased anger. The effect of external noise sources must also be considered for the external areas of the school, where when it exceeds 50 dB it may no longer be appropriate to carry out teaching activities, due to the interference that external sources can have on attention and the concentration. The negative health consequences of noise may be mediated through stimulation of the central stress response system, the hypothalamic-pituitary-adrenal (HPA) axis. Noise-induced activation of the HPA axis can result in sleep disturbances, increased heart rate, blood pressure, and increased stress hormone levels. Neurocognitive responses such as increased levels of anger may underlie an activation of stress mechanisms. Elevated stress hormone levels can directly contribute to the development of cardiovascular disease in a number of ways. A distinctive aspect of this HPA axis reaction is that it does not require cognitive understanding of environmental noise, which has led to noise exposure being termed the silent killer [8, 9].

4. INTEVRVENTION STRATEGIES

The evaluation of the link between the acoustic climate and the extra-auditory effects of noise in the school environment can make use of various strategies. First, measuring noise levels can discriminate between environments with an acoustic climate characterized by high or low sound pressure levels. It should be considered that, based on the recommendations of the World Health Organization, which indicates the 35dB limit in classrooms, and scientific evidence, noise levels higher than 58-60 dB increase the probability of the onset of extra-auditory disorders. The case studies have demonstrated noise levels even higher than 80 dB in some circumstances, in this case further increasing the possible onset of extra-auditory disorders but also noise-induced hearing disorders for certain individuals. If field measurement is not feasible, reference to similar scenarios and measurements taken can be a valid support for risk assessment. A fundamental step is the identification of the most disturbing sources and of the environments most at risk, where, for example, interactive teaching activities are carried out. The assessment of the age and type of pupils is also important for risk stratification, as the major source of disturbance for both students and teachers is represented by the noise level of the pupils themselves. It is also important to evaluate external noise sources, which although not considered directly disturbing, are known in the literature to have been associated with an increased incidence of important organic diseases, such as hypertension, heart disease, stroke, dyslipidemia and diabetes. Once the risk has been assessed, a suitable tool for deepening the interaction between the acoustic climate and possible pathologies is a survey, for example through questionnaires, which investigates the prevalence of these disturbances among students and workers. For workers, the company doctor, as a global workplace health consultant, can play a key role. The evaluation of the link between disturbance and acoustic climate can be investigated by the doctor during health surveillance, when it will be possible to highlight hypersensitive subjects or those who have already developed certain disturbances. Health surveillance is also a fundamental moment for the training of workers, with the possibility of promoting interventions for the prevention or possible treatment of noise disturbances. Once the link between the acoustic climate and workers' health has been assessed, the planning and implementation of actions to improve the acoustic climate will determine a process of continuous improvement of the workplace and therefore of the workers' occupational health.

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