UDK 613.86:534.323
DOI: 10.7562/SE2016.6.01.06
Review article
www.safety.ni.ac.rs

MILAN VELJKOVIĆ[1]
SNEŽANA ŽIVKOVIĆ[2]
MIODRAG MILENOVIĆ[3]

[1]University of Niš,
Faculty of Occupational Safety
[2]University of Niš,
Faculty of Philosophy
[3]University of Niš,
Faculty of Philosophy

[1]milan.veljkovic@znrfak.ni.ac.rs
[2]snezana.zivkovic@znrfak.ni.ac.rs
[3] mbmilenovic@gmail.com

PSYCHOPHYSIOLOGICAL IMPACT OF NOISE AS A STRESSOR

Abstract: *The paper deals with the issues related to noise as an environmental stressor by considering its influences on the human psychophysiological functioning, the psychosocial impacts and the psychological symptoms. In the first part of the paper, some basic concepts and definitions of stress and impact of stressors are given, while in the second part of the paper the basic mechanisms of psychophysiological response to stress and the studies dealing with noise as one of the most common environmental stressors are presented. The paper shows that the noise seriously affects the nervous system, both central and vegetative, which further influences the heart, blood vessels, blood pressure, digestive tract and many other organs and tissues, where many changes and functional disturbances including harassment, sleep disorders, cardiovascular disease and cognitive performance deficit are caused. Noise exposure is associated with psychological symptoms, but not with the clinically defined psychiatric disorder.*

Key words: stress, noise, environmental stressor, reactions.

INTRODUCTION

The increase in the number of companies and traffic, with the use of more powerful machines with greater capacity, which is economically more favorable, inevitably entails an increase in the intensity of the noise. Urbanization and urban traffic simultaneously worsen communal noise conditions. Noise is any undesirable or unpleasant sound phenomenon that, when certain intensity, affects the mental and physical status of human beings, plasters and reduces labor productivity and people's rest, as well as creates anxiety and mood [1]. It can also damage the functions of individual organs, as well as the health in general. The adverse impact of noise on health can be direct (defective hearing and deafness) or indirectly. The indirect effect of noise is reflected as the reduction of working ability and the occurrence of fatigue, the obstruction of understanding and communication, the reduction of concentration, the effect on the rest and sleep, as well as the occurrence of the health problems or the worsening of the existing ones.

In everyday life, people are usually exposed to numerous sources of stress. Various sources of stress have the potential interactive effects on the physical or psychological functioning of people which are different from simple effects. The effects of dealing with a source of stress can affect people's ability to cope with simultaneous or subsequent sources of stress or by reducing or improving the ability of an individual to adapt to another source of stress [2]. Several studies show that exposure to a source of stress in the environment, especially chronic, combined with acute sources of stress, can reduce an individual's ability to adapt psychologically and physiologically to another source of stress or can even increase the susceptibility to the later source of stress [3]. Dealing with a stress requires an effort and therefore can lead to fatigue or exhaustion of resources. Physiological and psychological changes caused by a source of stress may reduce a person's ability to respond to another source of stress. Cognitive fatigue causes many deficiencies in the control of behavior, which can be caused by the problem in sustaining attention or concentrating on tasks [3]. The increased irritability because of a noise source increasingly interferes with activities that require concentration and are repetitive. Based on the model to adapt to stress it can be assumed that in stressful situations the irritability due to noise requires either an extra cognitive effort of concentration or interferes with recovery from stress and fatigue at the cost of greater psychophysiological functioning. Results Tafalla and Evans [4] suggest, however, that the action can be performed under various stress conditions with an extra cognitive effort, but at a price of higher psychophysiological activation. The people under chronic stress (job stress, crowd) show the reduced physiological response (eg. blood pressure) and the later recovery from the acute sources of stress [5, 6]. Ouis [7] argues that "the irritability that people feel when faced with the noise is the most common visible symptom of stress that is accumulated inside." How one assesses and reacts to the environment depends not only on the external stressors, but also on several other factors, such as the personal factors, the environmental factors (time of day, season, etc.) and the past events or episodes that can affect the way individuals cope with external stressors at the time or over time

Conceptualization of stress

A broad basis for understanding the reaction of organism to the demands and challenges of the environment was determined by Claude Bernard and Charles Darwin in the nineteenth century. They touched, in their own way, the issues arising from the tension created as a result of adapting to the changes and challenges caused by the particular circumstances of the environment. By the mid-twentieth century, the generality and complexity of this subject began to move to a higher scientific level with building specific terminology. The first studies of stress are linked to the early works of Cannon [8] and Selye [9]. Cannon studied the reactions of animals and humans caused by dangerous situations. He noted that animals and people, when faced with emergency situations, provided the adaptive responses such as "fight or flee". He also demonstrated that these responses "fight or flee" meant the activation of the sympathetic-adrenal medullary (SAM) system. In the case of stress, this physiological system regulates the release of adrenaline, rapidly increases the blood pressure, the blood coagulation, the heart rate and the blood sugar level, reduces the pace of digestion and moves the energy resources into the muscles. It is important that the system, when the denger passes, returns to the levels of basic values. Cannon called this process homeostasis.

While Cannon studied the reaction to the acute danger, Selye was more interested in the adaptation of the body to chronic challenges. Stress represents the syndrome of the reactions that indicate that the man was or has been under the influence of a stressor. His model is based on the definition of stress as a non-specific (physiological) reaction, the bodily response to any request raised. The Selye's concept basically interprets endocrinal biochemical aspects of a stress which means the General Adaptation Syndrome (GAS). The most characteristic of this syndrome is its non-specificity, i.e. the stress acts as a response to each stress stimulus, regardless of its nature. The GAS passes through three stages: the stage of alarm that is analog to the Cannon's reaction "fight or flee", the stage of resistance where the body tries to cope with the new requirements or to adapt to them to and the stage of exhaustion where physical resources are becoming depleted, and may damage the system. Psychological stress models are developed independently of the biological model and are focused on the impact of psychological factors on the reactions to stress. Until now, the most known of these models is the transactional model developed by Lazarus and colleagues [10,11]. According to this model, the stress is a product of the interaction between the man and the environment. The stress does not arise only due to the occurrence of a stressful event, but the cognitive assessment of the event is also essential. Moreover, the coping strategies that a person uses to deal with this event are influential. All this affects the level of the perceived stress.

The theory of allostatic load [12] proposes a dynamic view of the stress as the constant bodily effort to achieve allostasis and stability through change. According to this theory, there is no ideal state of bodily functions. Each time a person confronts with a stressor, the physiological stress systems are activated to find a new balance that allows an individual to function in an altered state. The process of establishing allostasis is not without consequences, and a longer exposure to stressful situations requires the constant adaptation to a basic level of functioning, which can lead to a cumulative wear and fatigue of the body. Generally, the dominant conceptual framework in the study of stress has moved from the stability (homeostasis) to the adaptive change (allostasis) [13].

The effect of stressors on the human body

Depending on how the body and the mind cope with an acute or chronic stress, stressors can cause imbalances of the human system (mind-body connection), which immediately or over time can cause physiological, physical and psychological changes [14]. The personal factors such as the condition and properties of a person, as well as the previous exposures to stressors under different circumstances and other factors can affect the perception, coping and responds to these stressors (Figure 1).

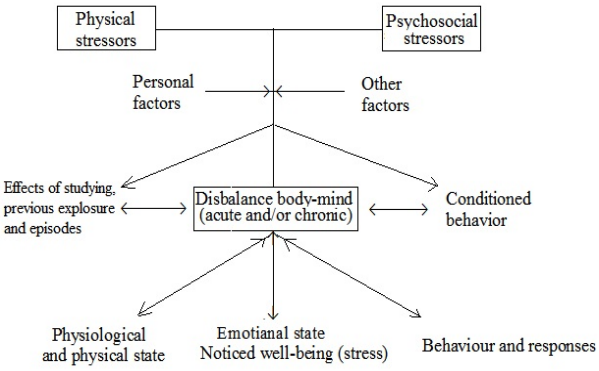

Figure 1. *Stressors, influencing factors and stress responses*

Human exposure to external stressors occurs through the senses. Receptors in the nervous system receive sensory information through sensors, such as the eyes, ears, nose and skin, which are stimulated by the bodily processes such as breathing, digestion and touch. External stress factors can affect the nervous, immune and endocrine systems, which can result in the mental and physical effects [15,16]. Our emotions and estimates are controlled by the limbic system and other parts of the brain, while the autonomic nervous system maintains the parasympathetic and sympathetic activities in balance. Defense of the human body against the (potential) diseases (eg. irritation, allergy, infection, toxicity) caused by the stimuli from the environment is controlled by the immune system

producing cytokines that are transported through the lymph system. The endocrine system sends and receives information via the blood vessels and endocrine glands, which produce certain hormones and provide boundary conditions for the "control" of stimuli from the environment through the immune and limbic systems. These systems are intertwined. Interactions can occur between stressors in complex exposure situations and in real life as well as between different bodily responses to the exposure. Our senses perceive independently, but the interpretation occurs jointly. In general, in order to truly assess the effects of stressors, all routes of exposure (both physiological and psychological) and all interactions among them and in the human system should be considered.

External stressors (mainly physical) cause an imbalance in the body's system by characteristic changes in the production of hormones and cytokines and other physiological processes in order to balance the body. Gee and Payne-Sturges [17] define the stress as a state of activation of physical and psychological readiness to act in order to help the organism to survive external threats. The stressors affecting the body for a long time can weaken the body's ability to face the challenges from the environment, which can cause the illness.

External stressors (physical and psychosocial), causing the stress, can cause the core of the adrenal gland to produce adrenaline and to prepare the body for the action "fight or flee" (via the sympathetic nervous system through the production of norepinephrine). If the stressor is limited in time and perceived in a timely manner, the parasympathetic nervous system does everything that the body regains the state of the balance. If the duration of the stress is prolonged, the production of CRF may affect the increased secretion of anti-stress glucocorticoids (e.g, cortisol) through the hypothalamic-pituitary-adrenal (HPA) axis. These hormones can lead to the physiological responses, such as rapid heartbeat, breathing, strength of heart contractions, arterial vasodilation of active muscles, vasoconstriction of the muscle that are not active and dilation of iris and bronchi. Under the acute stress, the activities regulated by the parasympathetic nervous system decreases (eg. the salivary and intestinal secretions for digestion and absorption of nutrients, rest and recovery), and the balance between the parasympathetic and sympathetic changes to the prevalence of sympathetic. If the prevalence of the sympathetic nervous system occurs frequently, the stress can interfere with all processes regulated by the parasympathetic nervous system [18]. One of the hormones which receives special attention in the literature is cortisol. It is proposed that:

- Too high level of cortisol can be harmful as it can degrade the immune system (lymph nodes atrophy and reduction of white blood cells) and to cause hypertension and vascular disorders;
- High level of cortisol, combined with the prevalence of the sympathetic nervous system, may contribute to the changes in the metabolism of carbohydrates and fats (leading to obesity), and cause anxiety, depression and heart disease;
- Reduced production of cortisol leads to the overactive immune response (eg., increased secretion of inflammatory cytokines in response to the low level of cortisol) in connection with the overactive sympathetic nervous system may result in fatigue, allergies, asthma and increased weight.

An imbalance of the brain-body connection can be caused by our allostatic load resulting chronic high or low activity of our system. Thus, the excessive or insufficient production of certain chemicals in our body, caused directly or indirectly by an excessive or insufficient stimulation of external stressors can exacerbate or impair the functioning of the system [14].

Noise exposure is associated with the changes in the levels of stress hormones and the cardiovascular changes. Also, the exposure to noise during the night affects the sympathetic and parasympathetic balance [19].

Physiological responses when exposed to noise

Exposure to noise causes a series of predictable short-term physiological reactions of the body which are managed by the autonomic nervous system. Exposure to noise causes the physiological activation, including an increase in the heart rhythm and the blood pressure, peripheral vasoconstriction and therefore an increased peripheral vascular resistance. There is a rapid adaptation to the short-term exposure to noise, but the adaptation to the prolonged exposure to noise is less certain [20]. Chronic noise produces the physiological stress [21, 22].

Noise causes the release of stress hormones which can negatively affect the health. Noise disturbs the homeostasis of the cardiovascular, endocrine and immune system and thus the body tries to cope with the demands of the environment that are assessed by the person as stressful. The imbalance between the demands of the environment and a person's ability to cope with the stress determines his/her possibility to overcome the stress caused by noise. The inability of the body to cope with the excessive noisy stimulation can lead to the adverse reactions to stress [23]. The glucocorticoid hormone cortisol is the primary product of neuroendocrine secretion cascade and a valid indicator of stress. Circadian profile of cortisol usually shows diurnal variations, is elevated in the morning and lowered in the evening.

In the models of noise, stress and disease, cortisol plays a key role in the activities of the HPA axis, as revealed by the studies where the subjects during the night are exposed to noise. Ising et al. [24] found that the exposure to noise levels above 53 dB during the night affected the increased secretion of cortisol, i.e. the examinees had significantly elevated levels of cortisol in the morning.

Interpretation of the results obtained by measuring the levels of cortisol caused by noise is quite complex [25]. However, there may be several factors that affect the variability in the levels of cortisol in the simulation of noise, such as measuring time, type of stressors, subjective sense of control of stressor source, individual differences are primarily reflected in the different characteristics of the response [26].

In some studies, exposure to high intensity noise in the industry is linked with the increased levels of norepinephrine and epinephrine [27]. In a study, the secretion of catecholamine is reduced when workers have ear protection against noise. Some studies, but not all, have shown elevated levels of cortisol caused by noise [28]. The general pattern of the endocrine response to noise indicates the noise as a stressor, causing the short-term physiological reactions of the organism. The noise affects the nervous system, the blood vessels, the digestive system and the hormonal system, which can be manifested by the increase in blood pressure, disorder in the work of digestion organs, especially the intestines, narrowing of the visual field and endocrine and metabolic disorders.

In the working conditions, the noise in combination with the stress at work, the dissatisfaction at work or complex tasks is associated with the increased blood pressure [29]. Also, the psychological habituation blocks the source of acute stress (noise) when doing certain complex tasks [4]. This is consistent with the fact that chronic or earlier stress can enable or increase the negative psychological and physiological effects of acute or subsequent sources of stress [2].

Characteristics and impact of noise

The problem is that the process of the impact of noise on health is very complex. People usually are not passive recipients of sound irritation and can develop coping strategies to reduce the impact of noise. If people do not like the noise, they can take steps to avoid it by moving away from a noisy environment, or if you are unable to move, by developing coping strategies. The noise is defined as any unwanted sound in the environment where people live and work, which causes discomfort or may adversely affect the health.

Noise causes numerous vegetative-visceral and psychological reactions of the organism. They are not equal in all animals and all people, and can range from mild transient symptoms to violent reactions and serious permanent damage, all of which, in most cases, depends on the intensity and characteristics of noise. If the noise exposure is chronic and exceeds certain levels, the negative health consequences can be observed. Although people tend to get used to the noise exposure, those able to fully adapt are rare.

Noise is typically characterized by intensity (eg. expressed in decibels), frequency (eg. tons), periodicity (continuous or intermittent) and duration (acute or chronic). Harmful effects of noise depend on its characteristics, as well as time exposure, weather volatility and direction of the noise, and finally the individual susceptibility of the person exposed to that noise. One of the main characteristics that affect the assessment of noise as unwanted is their volume or experienced intensity. The volume consists of sound intensity, tonal sound distribution and duration. The degree of adaptation to noise differs from person to person [30]. The sound is necessary but not sufficient to produce the noise. The psychological component of sound (eg. unwanted sound) and its physical components (eg. intensity) play a central role in the perception of noise.

The results of several studies suggest that the physiological effects and the health complaints are more closely associated with the subjective reactions to noise than with the physical characteristics of the noise [31,32].

Whether certain chronic occurrences in the environment, such as noise, are seen as a challenger of the stress depends on the cognitive processes of assessment. Cognitive assessment and the sense given to the sounds from the environment may affect the response to them - for example, the reaction to aircraft noise may vary between the employee at the airports and the residents who fear the long-term health effects from exposure to noise. Psychological factors (eg. behavior, sensitivity to noise) affect more the experience of noise as a stressor (50%) compared to the physical characteristics of the noise and the noise exposure itself (9-29%) [33].

Stansfeld et al. [32] have concluded that the people sensitive to noise "pay more attention to noise, better discriminate sounds, perceive the noise as more threatening and out of their control, are more responsive to noise and more slowly adapt to the noise than the people who are less sensitive.

For high frequency noise is found to be more irritated than the noise of low frequency [34].

The vibrations are seen as an addition to loud noise. In most studies of noise they are found to be an important factor in determining the inconvenience, especially because they are usually perceived through the other senses. Fields [35] found that, after controlling the level of noise, the disturbance caused by noise increases with the fear of the dangers of noise sources, sensitivity to noise, the belief that the noise cannot be controlled, awareness of others (unremarkable) impacts and the belief that the source of the noise is not important. The perception of the noise source control can reduce the risk of noise and the belief that it can be harmful. Also, maybe the noise is more harmful to health in the situations where several stressors interact and the total load can lead to the chronic sympathetic excitement or the condition of learned helplessness [36].

Other important psychological properties of sound include its predictability and the level of personal control of the sound source [37]. Unwanted, uncontrollable and unpredictable sound, either weak or strong, can be unpleasant and disturbing. The body

reacts to the inconvenience of the increased sound or noise through the complex psychological responses called stress.

What characterizes the noise as a stressor is that the person exposed to noise feels helpless and unable to do anything about it. This feeling that nothing cannot be done against the stress to change the discomfort and creates the impression that one has to live with it is called learned helplessness. An individual is expected only to relax and accept things as they are. The sense of helplessness is also used to exclude the psychological feeling that is associated with the stress of the noise.

In their study, Bronzaft et al. [38] concluded that only less than 20% of the people complaining about the noise actually managed to reduce or completely eliminate.When people complain to the authorities about the noise, they often come to the conclusion that nothing can be done about it. This leads to the feeling of "learned helplessness" when the person meets and reconciles with the situation and accepts it. However, this is not a healthy way of life because too energy is lost on adapting to the new situation.

Noise affects also the motivation. Individuals exposed to the noise in the laboratory are less persistent to do the motivational task carried out after removing the noise [39]. Since these effects are observed after removing stressors, these motivational effects are interpreted as aftereffects induced by the noise load during the operation. If individuals are able to control the noise, aftereffects are mitigated. Exposure to other environmental stressors, such as congestion and traffic jams, creates similar effects on motivation [40].

Weinstein [30] concluded that a critical or uncritical attitude to the assessment of environmental stressors explained a significant part of the experience of anxiety caused by noise. The tendency to be critical is associated with greater susceptibility to noise and greater sensitivity to other stressors from the environment. The people who are critical toward the stressors better discriminate the degree of the presence of stressors and have more negative attitudes toward them compared to the people who do not have a critical attitude.

Tafalla and Evans [4] have studied the effect of noise exposure on cognitive performance during high and low cognitive effort. The noise influenced the speed of solving arithmetic problems when the cognitive effort was low. The association between noise exposure and performing tasks was proved to be complex. Banbury et al. [41] concluded that the type of noise and the type of cognitive tasks used had different effects on the performance. The decline of the impact depended largely on the characteristics of the noise and had a negative impact on the memory.

The indirect impact of noise can cause a reduction in working capacity and fatigue, interfere with understanding and communication, reduce concentration, rest and sleep; also, there are certain health disorders, as well as the deterioration of the existing ones [42]. Noise affects the psychomotor and is characterized by the irritability, the deconcentration, the decrease in performance and the increase in accidents at work. The noise disturbs the sleep objectively, which cannot be reduced to objective complaints, because it is medically proved by electroencephalography [43].

Workers in offices (administrative staff) often emphasize that „the ability to concentrate, without the noise and other interference“should be one of the most important aspects of the working environment [44]. McDonald [45] noted psychological symptoms of stress in workers who worked in noisy environment. Also, the noise has a negative impact on job satisfaction. Shift workers are similarly at greater health risk if their occupations involve exposure to noise compared to those who work in relatively peaceful ambient conditions [46]. Also, at the workplace, non-auditive effects of noise have a large impact on the discomfort of the individuals and all employees. These factors include the meaning and content information of the noise (telephone conversations and discussions among colleagues), the predictability, the ability to avoid the noise, a sense of control and the control of the noise source, the request of the tasks and the attitudes towards the noise source [37].

Psychosocial effects and psychological symptoms

The risk of developing physical or mental illness that can be attributed to noise in the environment may be very small. As a conclusion, it seems that the noise in the environment is associated with psychological symptoms, but not with the clinical psychiatric disorder [47,48].

Psychosocial effects due to exposure to noise in the environment that have been studied in the epidemiological studies include discomfort, psychological welfare and psychiatric hospitalization. The main physiological effect of exposure to noise at work observed in the epidemiological studies is the unpleasantness. Unpleasantness caused by noise is the feeling of anger, discontent, discomfort or offense when noise interferes with one's thoughts, feelings or specific activities. It is not possible yet to predict any unpleasantness due to the noise on an individual basis because of the large number of different (partially unknown) endogenous and exogenous factors that affect the unpleasantness.

Bronzaft et al. [38] have identified six major emotional reactions to noise, and one of the major is anxiety. Anger (rage) was identified in 50% of patients. The people exposed to noise are under a constant stress. Anxiety is the most common response of the community in the population exposed to noise environment. Anxiety by noise can lead to disruption of daily activities, feelings, thoughts, sleep or rest and be followed by negative responses, such as anger, discontent or exhaustion and the symptoms related to stress [49]. In severe forms, one might think that it

affects the well-being and health. Due to the large number of people who are affected, anxiety contributes significantly to the burden of disease from the environmental noise [50]. The social and cultural values, personal characteristics (eg, age and sensitivity to noise) and situational characteristics (eg. soundproofing of apartments) can affect the individual level of tension [49,51]

Symptoms such as nausea, headache, quarrelsome behavior, changes in mood and anxiety are found for industrial workers exposed to high levels of noise in working environments, such as schools [52] and plants [53]. However, it is difficult to interpret many of these industrial studies because the workers are also subjected to other stressors, such as physical hazards and heavy duty requirements, in addition to the excessive noise. Interviewing of the community has revealed that a high percentage of people reported "a headache", "nightmares" and "tension and nervousness" in the high-noisy areas [54,55]. The high levels of noise in the environment are associated with more subsyndromal conditions, such as psychiatric disorders and anxiety, but with a specific syndrome, such as, for example, depression [56].

A study that included the people living in a noisy environment near the Elmas airport in Sardinia, Italy, showed that these individuals were at risk of developing long-term status of syndromal anxiety (generalized disorder of anxiety and anxiety disorder), which confirmed the hypothesis about the sustainability of the central nervous system excitement caused by the noise [44].

Non-auditive effects of noise can cause anxiety, fear of noise sources and the feeling that the noise cannot be avoided. In a laboratory study, Standing and Stace [57] investigated the state and trait of anxiety, that is the anxiety related to the specific situation and the anxiety as a personality trait. The anxiety as a personality trait differs significantly among the subjects and is not dependent on the level of the noise. They found that noisy conditions increase the state of anxiety depending on the intensity level and in all three subgroups with different personality traits that are associated with anxiety. This indicates that anxiety is a part of the personality traits and that it depends on the personal characteristics, and partly on the situation.

Sensitivity to noise, increased perception of sounds from the environment, may partially explain the response to noise and is considered as personality traits. Also, the people sensitive to noise probably tend to be susceptible to other stressors from the environment, as well as they can be associated with neuroticism [34].

Miedema and Vos [58] concluded that the relationship between fear and harassment depends on either personal experience of fear or may be the result of a joint predisposed people to a feeling of fear and harassment. Communication can reduce feelings of fear and thus reduce anxiety due to the noise, but such an effect is not expected when the predisposition to fear is primary and significantly greater cause of anxiety from noise, because the personal characteristics will depend on the information or communications from the environment.

Continuous exposure to noise interferes with the psychological aspect of proper human communication. In some cases, the performance of certain tasks can be more difficult because the adverse environmental stimuli affect the mechanics of carrying out tasks. For example, the sound emitted by the part of the equipment can be so loud that the worker does not hear an important signal while performing a job. These disturbances can produce long-term consequences that are manifested by a reduced tolerance of frustration and an increased threshold of response. Even minimal noise can cause an increase in anxiety and aggressive and hostile behavior as well as a reduced altruistic behavior [59].

Mental stress can be manifested itself in other ways, generally through the aggressive behavior. As stated in the study of Bronzaft et al. [38], anger is one of the most common responses of an individual to the noise and often results in violence. In the newspaper story, it is often mentioned that neighbors provoked riots because of the loud music.

Effects of traffic noise

Bronzaft et al. [38] have made a list of the problematic sources of noise: loud music, loud movies, restaurants, garden supplies, recreational vehicles, bars, nightclubs, traffic noise, etc. The most prominent source of noise of all is traffic noise. Traffic noise worsens the effect of solving the tasks of search and memory [60], and has an impact on the short-term memory and solving mentally the arithmetic tasks [61]. It has been found that the noise has an impact on cognitive resources. The studies have shown the negative effects on the tasks of concentration, attention [62] and the results in the tasks of search and recall [63], as well as the results of detection and memorization of numbers that are repeated [64]. Stansfield at el. [47] have shown that road traffic can lead to the increased anxiety, which confirms previous results.

Miedema and Vos [65] noted that anxiety and sensitivity to noise are associated and sensitivity to noise plays an important role in creating the anxiety caused by noisy air traffic.

Miedema and Vos [58] showed that the presence of the feeling of fear has a substantial and significant impact on the perceived anxiety caused by loud sound source. This effect of noise may have road, rail and air traffics. Taking into account the statistical variation within and between different studies, Miedema and Vos [66] showed that aircraft noise is statistically the most disturbing and that the train noise is less disturbing than the road traffic noise.

Some studies have found a dose-response connection: the exposure to higher levels of military aircraft noise around the airport Kadena in Japan is associated with

depression and anxiety in the form of the dose-response dependence [67], while road traffic noise is associated with the symptoms of poor mental health after adjusting for age, gender, income and length of stay [68]. The residents living near airports and exposed to constant noise showed the increased mental instability, depression, impatience and irritability [67].

CONCLUSION

Noise as an environmental stressor can cause both short- and long-term effects on the physical and mental health of a person. More and more attention is paid to low-intensity noise, which does not damage hearing, but can lead to other health disorders. In addition, the noise as a stressor affects the endocrine and immune system. Non-auditive health disorders are the expression of physiological reactions to stress. These psychological reactions are characterized by high blood pressure, increased secretion of certain hormones, changes in heart rhythm and slowing of the digestive system. If the noise and the stress caused by it continues, the permanent damage and disease in cardiovascular, circulation and gastrointestinal systems can be caused. Therefore, the stress caused by noise can affect many organs indirectly. Chronic noise has a negative impact on people on both the psychological and behavioral level. This affects the performances and can alter the ability to held attention, and reduce the ability of memory. All this may be accompanied by fatigue, irritability, insomnia and vegetative disorders of various degrees.

The work that takes place in a noisy environment is performed with the increased effort, while the general metabolism and the energy consumption grow. This is particularly reflected onto the mental effort and concentration, so the injuries at work are more often. Because of mental and motor nuisances, the work of both physical and intellectual workers is significantly hindered in large noise. The fine motor coordination is primarily disturbed, the reaction loses its speed and quality, the distorted sharpness of perception and judgment occurs, so the number of injuries and accidents increases. The anxiety related to the noise is very prevalent in today's society. Even if discomfort as such is not directly canceling, there are indications that serious health consequences can occur for vulnerable people or in cases of simultaneous exposure to other stressors from the environment or to the social stresses.

It was found that the observed control and predictability of noise are important in determining the effects and consequences of the exposure to noise. Indeed, even the prediction of situations with loud noise in the absence of actual exposure to noise can affect performance, unless the person is assumed that will have the control over the noisy situation. Noise can reduce the altruistic behavior, increase the aggression and affect the social interaction between people. Also, the absence of the extreme stress and discomfort will ensure a quality way of life. If the concept of good quality health was expanded by including good quality of life, there would be more evidences that the noise has a negative impact on human life and health. Undoubtedly, there is a need for further research to clarify this complex area, including better measurement of noise exposure and health outcomes. In addition, there should be more emphasis on the field studies using longitudinal investigation with a careful selection of samples in order to avoid unnecessary biases related to the previous exposure to noise.

REFERENCES

[1] Obrenović, J. (2003). *Psihofiziologija rada.* Niš:

Filozofski fakultet.

[2] Lepore, S. J., & Evans, G. H. (1996). Coping with multiple stressors in the environment. In M. Zeidner, & N. S. Endler (Eds.), Handbook of Coping (pp. 350–377). New York: Wiley.

[3] Cohen, S. (1980). After effects of stress on human performance and social behavior: A review of research and theory. *Psychological Bulletin*, 88, 82–108.

[4] Tafalla, R. J., & Evans, G. W. (1997). Noise, physiology, and human performance: The potential role of effort. *Journal of Occupational Health Psychology*, 2(2), 148–155.

[5] Siegrist, J., & Klein, D. (1990). Occupational stress and cardiovascular reactivity in blue-collar workers. Work & Stress, 4, 295–304.

[6] Schaubroeck, J., & Ganster, D. C. (1993). Chronic demands and responsivity to challenge. *Journal of Applied Psychology*, 78, 73–85.

[7] Ouis, D. (2001). Annoyance from road traffic noise: A review. *Journal of Environmental Psychology, 21, 101–120.*

[8] Cannon, W. B. (1932). *The wisdom of the body*. New York: Norton.

[9] Selye, H. (1956). *The stress of life*. New York: McGraw-Hill.

[10] Lazarus, R. S. (1966). *Psychological stress and the coping process.* New York: McGraw-Hill.

[11] Lazarus, R. S., & Folkman, S. (1987). Transactional theory and research on emotions and coping. *European Journal of Personality, 1,* 141–170.

[12] McEwen, B. S. (1998). Stress, adaptation, and disease: Allostasis and allostatic load. In S. M. McCann, J. M. Lipton, E. M. Sternberg, G. P. Chrousos, P. W. Gold, & C. C. Smith (Eds.), *Annals of the New York Academy of Sciences, Vol. 840: Neuroimmunomodulation: Molecular aspects, integrative systems, and clinical advances.* New York: New York Academy of Sciences, pp. 33–44.

[13] Ganzel, B. L., Morris, P. A., & Wethington, E. (2010). Allostasis and the human brain: Integrating models of stress from the social and life sciences. *Psychological Review, 117,* 134–174.

[14] Hellhammer, D.H., Hellhammer, J. In: Riecher-Rössler, A., Steiner, M., editors. Stress the brain-body connection, key issues in mental health, vol. 174. Switzerland: Karger; 2008.

[15] Vroon, P.A. (1990). Psychologische aspecten van ziekmakende gebouwen [Psychological

aspects of building related illness]. The Netherlands: Ministry of Housing, Planning and Environment, ISBN 90-5187-031-0; [in Dutch].

[16] Kapit, W., Macey, R.I., & Meisami, E. (2000). The physiology coloring book. 2nd ed. CA, USA: Benjamins/Cummings Science Publishing.

[17] Gee G, Payne-Sturges D. Environmental health disparities: a framework for integrating psychosocial and environmental concepts. Environ Health Perspect 2004;112:1645e53.

[18] Clougherty JE, Kubzansky LD (2009). A framework for examining social stress and Susceptibility to air pollution in respiratory health. Environ Health Perspect;117:1351e8.

[19]Graham JMA, Janssen SA, Vos H, Miedema HME (2009). Habitual traffic noise at

home reduces cardiac parasympathetic tone during sleep. Int J Psychophysiol;72:179e86.

[20] Vallet M, Gagneux J, Clairet JM *et al(*1983). Heart rate reactivity to aircraft noise after a long -term exposure. In: Rossi G (ed) *Noise as a Public Health Problem*. Milan: Centro Recherche e StudioAmplifon,; 965–75.

[21]Evans, G. W. (2001). Environmental stress and health. In A. Baum, T. Revenson, & J. E. Singer

[22]Ising, H., & Kruppa, B. (2007). Stress effects of noise. In L. Luxon & D. Prasher (Eds.), *Noise and its effects* (pp. 516–533). Chichester: Wiley. (Eds.), *Handbook of health psychology* (pp. 365–385). Hillsdale, NJ: Erlbaum.

[23] Prasher, D. (2009). Is there evidence that environmental noise is immunotoxic? Noise & Health, 11(44), 151-155

[24] Ising, H., Lange-Asschenfeldt, H., Moriske, H. J., Born, J., & Eilts, M. (2004). Low frequency noise and stress: Bronchitis and cortisol in children exposed chronically to traffic noise and exhaust fumes. Noise & Health, 6(23), 21-28

[25] Babisch, W. (2003). Stress hormones in the research on cardiovascular effects of noise. Noise & Health, 5(18), 1-11

[26] Miller, G. E., Chen, E., & Zhou, E. S. (2007). If it goes up, must it come down? chronic stress and the hypothalamic-pituitary-adrenocortical axis in humans. Psychological Bulletin 133(1), 25-45

[27] Cavatorta A, Falzoi M, Romanelli A *et al*(1987). Adrenal response in the pathogenesis of arterial hypertension in workers exposed to high noise levels. *J Hypertens*; **5**:463-6

[28] Brandenberger G, Follenius M, Wittersheim G, Salame P. (1980). Plasma catecholamines and pituitaryadrenal hormones related to mental task demand under quiet and noise conditions. *Biol Psychol*; **10**: 239–52

[29]Melamed, S., Fried, Y., & Froom, P. (2001). The interactive effects of chronic exposure to noise and job complexity on changes in blood pressure and job satisfaction: A longitudinal study of industrial employees. *Journal of Occupational Health Psychology*, 6, 182–195.

[30] Weinstein, N.D. (1980). Individual differences in critical tendencies and noise annoyance. *J. Sound Vib*., 68, 241–248.

[31]Passchier-Vermeer, W., & Passchier, W. F. (2000). Noise exposure and public health. *Environmental Health Perspectives Supplements*, 108(1), 123–131.

[32] Stansfeld, S.; Haines, M.; Brown, B. (2000). Noise and health in the urban environment. *Rev. Environ. Health*, 15, 43–82.

[33] Bell, P. A., Greene, T. C., Fisher, J. D., & Baum, A. (2001).Environmental psychology. *Fort Worth: Harcourt.*

[34] Bjork EA. (1986). Laboratory annoyance and skin conductance responses to some natural sounds. *J Sound Vib*; **109**: 339–45

[35] Fields JM. (1984). The effect of numbers of noise events on people's reactions to noise. An analysis of existing survey data. *J Acoust Soc Am*; **75**: 447–67

[36] Seligman, Martin E. P. (1975). Helplessness: On Depression, Development, and Death. *San Francisco: W.H. Freeman.*

[37] Jonsson, E.; Sörensen, S. (1970). Relation between annoyance reactions and attitude to source of annoyance. *Public Health Rep*., 85, 1070–1074.

[38] Bronzaf t, A. L., Deignan, E., Bat-Chava, Y., & Nadler, N. (2000). I ntrusive communit y noises yield more complaints. *Hearing Rehabilitation Quarterly, 25*, 16 –22, 34.

[39] Boman, E., and S. Hygge. (2000). Aftereffects of noise predictability and task load on motivation. *INTER-NOISE and NOISE-CON Congress and Conference Proceedings*. Vol. 2000. No. 8. Institute of Noise Control Engineering,

[40] Evans, G. W., & Stecker, R. (2004). Motivational consequences of environmental stress. *Journal of Environmental Psychology*, *24*(2), 143-165.

[41] Banbury, S. P., Macken, W. J., Tremblay, S., & Jones, D. M. (2001). Auditory distraction and short-term memory: Phenomena and practical implications. *Human Factors*, 43(1), 12–29.

[42] Smith AP, Broadbent DE.(1992). *Non-auditory Effects of Noise at Work: A Review of the Literature*. HSE Contract Research Report No 30, London: HMSO,

[43] Muzet A. Environmental noise, sleep and health. *Sleep Med Rev*. 2007; 11:135–42. [PubMed: 17317241]

[44] Louis Harris & Associates, Inc. (1980). The steelcase national study of

office environments, no. 2. *Grand Rapids, MI: Steelcase Inc.*

[45] McDonald, N. (1989). Jobs and their environment: The psychological

impact of work in noise. *The Irish Journal of Psychology*, 10, 33–50.

[46] Manninen, O. (1990). Interaction studies on environmental factors: recent findings. In B. Berglund & T. Lindvall, (Eds.), Proceedings of the fifth international congress on noise as a public health problem, Vol. 5 (pp. 209–232). *Stockholm: Swedish Council for Building Research.*

[47] Stansfeld, S.; Gallacher, J.; Babisch, W.; Shipley, M. (1996**).** Road traffic noise and psychiatric disorder: Prospective findings from the Caerphilly study. *Brit. Med. J., 313*, 266–267.

[48] Hardoy MC, Carta MG, Marci AR, et al.(2005). Exposure to aircraft noise and risk of psychiatricdisorders: the Elmas survey -- aircraft noise and psychiatric disorders. *Soc Psychiatry Psychiatr Epidemiol*.; 40(1):24-26

[49] Ohrstrom E, Skanberg A, Svensson H, Gidlof-Gunnarsson A. (2006) Effects of road traffic noise and the benefit of access to quietness. J Sound Vibrat.; 295:40–59.

[50] Fritschi, L.; Brown, AL.; Kim, R.; Schwela, DH.; Kephalopoulos, S.(2011). Burden of disease from environmental noise. *Bonn: World Health Organization;*

[51] Janssen SA, Vos H, Eisses AR, Pedersen E.(2011). A comparison between exposure-response relationships for wind turbine annoyance and annoyance due to other noise sources. *J Acoust Soc Am*.; 130:3746–53. [PubMed: 22225031]

[52]Crook MA, Langdon FJ. (1974). The effects of aircraft noise in schools around London Airport. *J Sound Vib*; **34**: 221–32

[53]Melamed S, Najenson T, Luz T *et al*. (1988)Noise annoyance, industrial noise exposure and psychological stress symptoms among male and female workers. In: Berglund B (ed) *Noise 88: Noise as a Public Health Problem. Vol. 2. Hearing, Communication, Sleep and Non-auditory Physiological Effects*. Swedish Council for Building Research,; 315–20

[54] Jones DM, Chapman AJ, Auburn TC. (1981). Noise in the environment: a social perspective. *J ApplPsychol*; **1**: 43–59

[55] Finke HO, Guski R, Martin R *et al.* (1974). Effects of aircraft noise on man. *Proceedings of the Symposium on Noise in Transportation*, Section III, paper 1. Southampton: Institute of Sound and Vibration Research,

[56] Stansfeld, S. A., Haines, M. M., Berry, B., & Burr, M. (2009). Reduction of road traffic noise and mental health: An intervention study. *Noise & Health*, 11(44), 169-175

[57] Standing, L.; Stace, G. (1980). The effects of environmental noise on anxiety level. *J. Gen. Psychol., 103*, 263–272.

[58] Miedema, H.M.E.; Vos, H. (1999**).** Demographic and attitudinal factors that modify annoyance from transportation noise. *J. Acoust. Soc. Amer., 105*, 3336–3344.

[59] Gregurek R. , Gozmi M. et al. (2005). *Buka i zdravlje*, Akademija medicinskih znanosti Hrvacke, Zagreb,

[60] Hygge, S., Boman, E., & Enmarker, I. (2003). The effect of road traffic noise and meaningful irrelevant speech on different memory systems. *Scandinavian Journal of Psychology*, 44(1), 13–21.

[61] Belojevic, B., *Ohrstrom*, E., & Rylander, R. (1992). Effects of noise onmental performance with regard to subjective noise sensitivity. *International Archives of Occupational and Environmental Health*, 64, 293–301.

[62] Smith, A. P. (1991). Noise and aspects of attention. *British Journal of Psychology*, 82, 313–324.

[63] Smith, A. P., & Miles, C. (1987). The combined effects of occupational health hazards: an experimental investigation of the effects of noise, night-work and meals. *International Archives of Occupational and Environmental Health*, 59, 83–89.

[64] Smith, J., Ockenfels, M. C., Porter, L., Kirschbaum, C., Hellhammer, D. H., & Stone, A. A. (1998). Stressors and mood measured on a momentary basis are associated with salivary cortisol secretion. *Psychoneuroendocrinology*, 23(4), 353–370.

[65] Miedema HME, Oudshoorn CGM. Annoyance from transportation noise: relationships with exposure metrics DNL and DENL and their confidence intervals. *Environ Health Perspect*. 2001; 109:409–16. [PubMed: 11335190]

[66] Miedema HM, Vos H. (1998). Exposure-response relationships for transportation noise. *J Acoust Soc Am* 104:3432-3445

[67] Hiramatsu K, Yamamoto T, Taira K, Ito A, Nakasone T. (1997). A survey on health effects due to aircraftnoise on residents living around Kadena airport in the Ryukyus. *J Sound Vib*; **205**: 451–60

[68] Halpern D. (1995). *Mental Health and the Built Environment. More than Bricks and Mortar?*London: Taylor & Francis Ltd

ACKNOWLEDGEMENTS

This paper is part of the Project etc. III-43014 that is finansed by MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGICAL DEVELOPMENT of Republic of Serbia.

BIOGRAPHY

Milan Veljković was born in 1987 in Leskovac, Serbia, where he completed his elementary and high school. He completed his undergraduate and master academic studies at the Department of Psychology, the Faculty of Phylosophy, University of Niš, Niš, Serbia. Now, he is a PhD student in the same department. He works as a researcher associate at the Faculty of Occupational Safety, University of Niš.

PSIHOFIZIOLOŠKI UTICAJ BUKE KAO STRESORA

Milan Veljković, Snežana Živković, Miodrag Milenović

Apstrakt: *U ovom radu smo se bavili pitanjima buke kao stresora životne sredine i razmatrali smo uticaje buke na psihofiziološko funkcionisanje čoveka, kao i na psihosocijane efekte i psihološke simptome.*
U prvom delu rada date su neke osnovne koncepcije i definicija stresa i uticaj stresora, dok je u drugom delu rada dat prikaz osnovnih psihofizioloških mehanizama reagovanja organizma na stres i prikaz istraživanja koja su se bavila bukom kao jednim od najčešćih stresora životne sredine.
Iz rada može da se zaključi da buka ozbiljno pogađa nervni sistem, kako centralni, tako i vegetativni, a preko ovoga utice na srce, krvne sudove, krvni pritisak, digestivni trakt i mnoge druge organe i tkiva, u kojima izaziva promene i funkcionalne smetnje uključujući uznemiravanje, poremećaj sna, kardiovaskularne bolesti, i deficit kognitivnih performansi. Izloženost buci povezana sa psihološkim simptomima, ali ne i sa klinički definisanim psihijatrijskim poremećajem.

Ključne reči: stres, buka, stresori, životna sredina, reakcije.