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Estimation of Acting Factor in Stress from Motorbike Sounds

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Abstract—In the presented study, the search for the acting force in stressor acoustic signal and common everyday acoustic signal is presented. As stressors the signals of acoustic siren of air raid alert and other dangers in the different counties were used, and as everyday signals the sound of motorbikes passing by observers were used. In total five different signals of alert sirens were used. Numerical values presented in research were obtained via frequency analysis with Hann's window and later – via spectrogram survey. This survey allowed us to find the presence of a steady frequency components in the observed signals, and, most importantly, the presence of rises and falls in said components. These changes in frequency had their speed of change calculated for sirens and motorbikes. For the rise of frequency mean speed in the siren group was calculated as 164 Hz/second, fall was 80 Hz/second. For the motorbike, the speed of frequency rise had a mean value calculated as 166 Hz/second and fall of frequency was estimated as 67 Hz/second. Possible sources for said effect in motorbike signals are Doppler effect and rise of RPM during acceleration. During the statistical analysis via implementation of the non-parametric method due to the character of data distribution in the studied group the lack of statistically meaningful differences between speeds of frequency rise in frequency components of the signals was found. Said rise is presumed to be the acting factor in stress from everyday sounds.

***Keywords* — stress-inducing sounds, sirens, frequency analysis, spectrogram, non-parametric test.**

I. Introduction

A warning system is a mechanism of receiving information about an oncoming emergency, spreading that information to those who need it and enabling informed decisions and swift responses by individuals in danger. There are different types of emergencies that may occur nowadays such as geophysical and biological hazards, complex socio-political emergencies, industrial hazards, personal health risks, etc [1], [2].

Each country has its own system of informing residents of impending risk. But effective warning systems are a people-centered complex which consists of four related components: risk knowledge, warning service, communication and dissemination, and response capability [3]. And one of the most valuable parts of each warning system is the alarm which usually includes a specific audio signal that helps people to acknowledge the message fast and ensures clear communication between responsible institutions and the public.

With the full-scale invasion of Ukraine alarms became a part of the life of every citizen of the country. As of February 24, 2022, a total of approximately 38,260 alarms were announced in Ukraine [4]. In Kyiv alone, since February 24, 1,055 alarms have been sounded. The danger lasted for 1209 hours and 59 minutes [5]. It is common knowledge that effective communication with the public in the wartime is a great strategy for saving lives. Recent studies show that 35 to 45% of observed civilian casualties were avoided because of public responsiveness to the messaging system [6].

It is also known that frequent airstrikes (using different types of weaponry) and alerts are used as an additional source of psychological warfare for a civilian population [7]. Over time, alarms can become increasingly associated with uncertainty, panic, and fear therefore the very sound of it becomes stressor and trigger itself [8].

Modern studies often bypass the stress aspect or acting factor of an alert. Most common aspects of them are the effectiveness [9] and range effect of them [10]. There are also studies dedicated to the political and social aspects related to the siren alert systems [11].

A. Dangers of the stress

Psychological stress occurs when environmental, physical, and/or psychological demands exceed perceived resources available to respond to a particular situation. For that reason, stress can be viewed as a dynamic process [12]. Stress can affect health both directly, by triggering autonomic and neuroendocrine

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reactions, and indirectly, by prompting changes in health-related behaviors. Additionally, it has an impact on various biological systems within the body. Stress can modify the production of stress mediators in ways that may that can both increase and blunt, both upregulate and downregulate and in future lead to significant implications for health and have detrimental effects on immune function which may lead to delayed wound healing, diminished responses to vaccination, and the onset and progression of cancer. Chronic stress poses particular challenges for elderly individuals due to the gradual decline in immune function that occurs with aging [13], [14], [15].

Stress can affect appetite and normal function of the gastrointestinal tract. It can increase intestinal bacteria counts, visceral irritability and modify permeability of the intestinal barrier [16]. Stress is also associated with shortened sleep, fragmentation, and possibly a reduction in sleep stages 3 and 4. That can cause increases in levels of traditional stress markers and can therefore worsen the effects of stress [17].

Stress can impact memory in various ways such as either impairing or enhancing memory processes that rely on the hippocampus. Moreover, stress experienced during critical periods of brain development may preprogram subsequent memory performance therefore it can be dangerous for children [18].

It is also known that extended periods of intense psychological stress can lead individuals to develop somatic symptoms, which may progress to mental illnesses. Stressful life events and circumstances are also associated with the onset and recurrence of major depression. In all categories of mental disorders, the stressful situation or event significantly influences the onset and manifestation of symptoms [7], [19], [20]. Prolonged stress overall can lead to severe neurological disorders, heart issues like heart attacks, asthma, diabetes, headaches, accelerated aging, and even premature death [21]

A stressor is any factor or event that induces stress. It can take various forms such as physical or physiological changes within the body, alterations in the environment, life events, or even unreal or imaginary situations. When the body is exposed to a stressor it initiates a response aimed at overcoming the perceived challenge but individual responses to psychological stressors can vary significantly [22], [23]. Therefore, every little thing related to the cause of stress in future can ignite the stress response or remind the individual about his previous experience.

The brain itself makes and stores associations between the sensory information (e.g., sights, sounds, smells, positions, and emotions) from that specific event allowing the individual to generalize to sensory information present in current or future events. At each level of the brain, incoming input is interpreted and compared to previous similar patterns of activation. The occurring match triggers a response which is crucial for swiftly reacting to potentially threatening sensory signals. For that reason, the sensory signals which were associated with stress in the past will be associated with stress in future. However, this mechanism often can lead to experiencing stress responses to non-threatening situations as patterns of incoming sensory information may be interpreted as 'danger' and acted upon in milliseconds before the information gets to the cortex to be interpreted as 'harmless'. It is especially true if the incoming sensory information shares similarities with the previous experience such as the sound of fireworks can be associated with the sound of explosions and therefore be stressful for soldiers or civilians that experienced airstrike [24]. In extreme situations such as post-traumatic stress disorder, reliving episodes can be triggered involuntarily by specific reminders that relate in some way to the circumstances of the trauma [25].

That leads us to the current problem.

B. Problem statement

It is clear that despite being crucial life-saving tool alarms are widely associated with the stress and uncertainty of war. For that reason, the audio signal that accompanies it became a stressor itself. However sometimes people can confuse stress – related cues with non-threatening and experience the same emotions or states before the brain can identify its safety especially if there are similarities between the two. That can also relate to the alarms.

Unfortunately, sometimes for a lot of people sounds occurring in day-to-day life can bear resemblance to the sounds associated with previous stressful experiences. And the most obvious in relation to the air-raid alarm in Ukraine we would like to name is a sound of a motorbike either passing by or speeding up – based upon the author's subjective experiences in daily life. But the main problem is to understand exactly why the sound of a motorbike can remind us of the sound of an alarm and using acquired info to find more of stressor signals to develop policies, designed to minimize the influence of stressing signals on the populace.

II. IV. Materials and Methods

A. Used siren signals

As the first step of a study we used subjective analysis of the present in the web sounds of the civil warning systems of different origins – from different countries and objects of danger. Next step of investigation was in calculation of the spectrograms and spectrums for each one of them. Said spectrograms were obtained via usage of the Audacity program product. In total five spectrograms were created. The first siren is from Odessa [26], its spectrum is shown on Fig. 1. Amplitudes on presented spectrums are normalized in a way that a 0 dB sine wave –

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a pure tone – will be at 0 dB on the graph [27]. So, all amplitudes of frequencies are to have negative value in dB if they do not reach that level.

Said spectrum was obtained via implementation of a Hann window and has shown the presence of a signal peak at 320 Hz and number of lesser peaks on different frequencies up to 1 kHz.

Spectrogram of the said signal is presented on Fig. 2. Calculated fragments were 8 seconds long and four fragments were studied for rise and fall of frequency components.

Said spectrogram shows the presence of a number of rises and falls spectral components. Spectral components in question are straight lines freely observable on the graph of the spectrogram. Character of the changes in them is akin to the Doppler effect and it is noticeable that rise of frequency in a signal is more steep than fall. Majority of spectral components were present in a low frequency domain. This fact may prove to hamper the possibility of implementation of musical therapy to correct the stress impact due to impactors residing in the same frequency domain as a musical signal, often used in said therapy[28].

Next signal is that of a German fire brigade [29]. Spectrum also was obtained via implementation of Hann's window.

Presented image also shows the presence of a higher number of frequency peaks, although this time they are in the domain of higher frequencies. The spectrogram of said signal is shown on Fig. 4. Observed fragments were 15 seconds long and four fragments were studied for rise and fall of frequency components.

The analysis of an acquired spectrogram had also shown the presence of rises and falls in frequency components with the steeper rise and prolonged fall.

Next signal observed was Switzerland [30] general alarm. Its spectrogram is presented on Fig. 5.

During the inspection of an obtained spectrogram had also been found the presence of rises and falls in frequency components.

Next step was in estimation of a French alert [31] signal. Its spectrogram is shown on Fig. 6. Observed fragments were 15 seconds long and four fragments were studied for rise and fall of frequency components.

The observation of a calculated spectrogram had also shown the presence of rises and falls in frequency components with the steeper rise and prolonged fall.

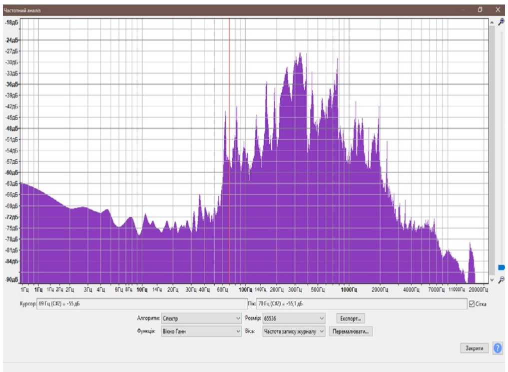

Fig. 1. Spectrum of Odessa siren

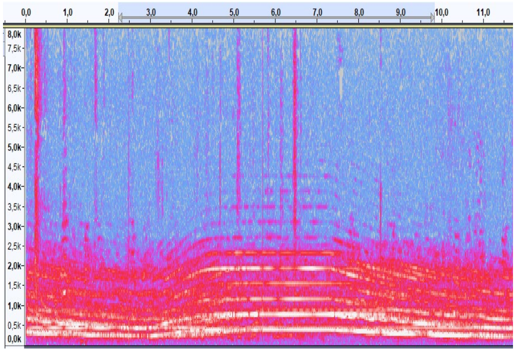

Fig. 2. Spectrogram of Odessa siren

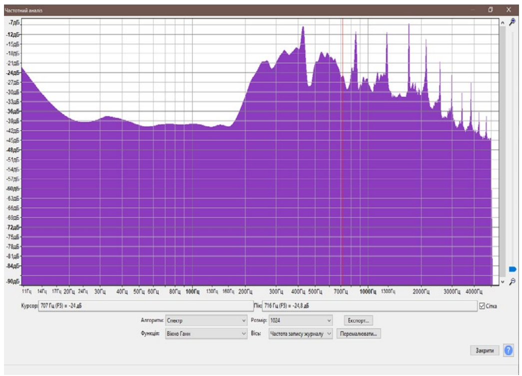

Fig. 3. Spectrum of German siren

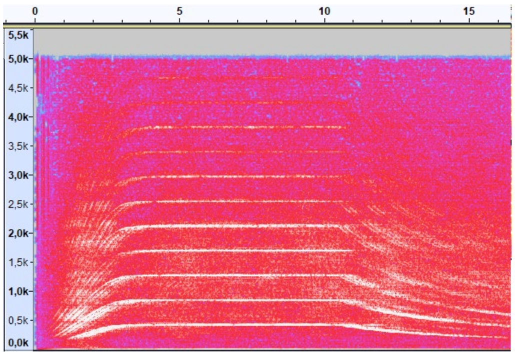

Fig. 4 Spectrogram of German siren

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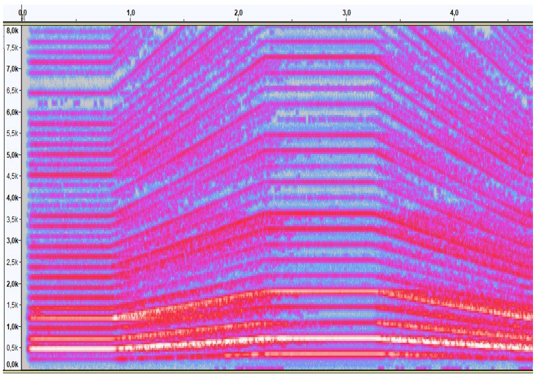

Fig. 5 Spectrogram of Switzerland siren

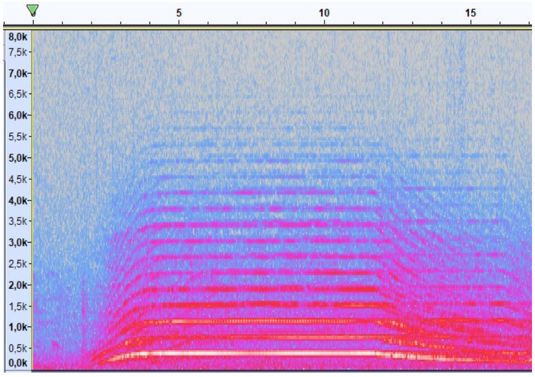

Fig. 6 Spectrogram of French siren

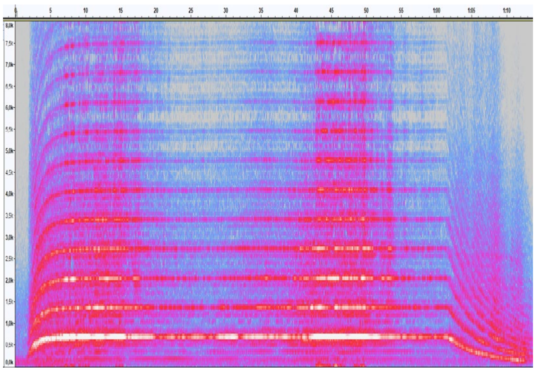

Fig. 7 Spectrogram of USA siren

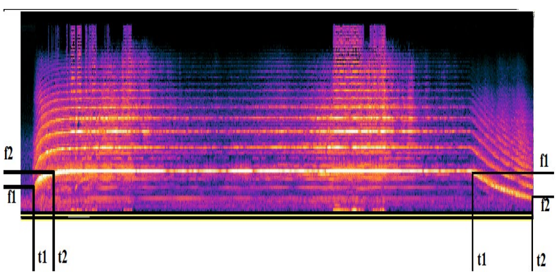

Fig. 8 Data acquisition scheme

Final step in the analysis of sirens was the analysis of a USA siren. The obtained spectrogram is shown on Fig. 7. Observed fragments were 75 seconds long and two fragments were studied for rise and fall of frequency components.

This spectrogram also shows the presence of previously observed frequency component behavior.

Calculation of a numeric representation of said effect was conducted in the next way – via usage of a formula (1) on a spectrogram fragment with observed rise and fall effect:

$$\Delta f_s = \frac{|f_2 - f_1|}{t_2 - t_1}, \quad (1)$$

In said formula f1 is the starting frequency of a calculated fragment (rise or fall), f2 - ending frequency of a calculated fragment, t1 – starting time of a calculated fragment, t2 - ending time of a calculated fragment. The way data was obtained is presented on Fig. 8.

From the presented formula the speed of rise and fall of the observed frequency components was obtained. Said speeds were grouped for rises and falls in them. There were 2 groups that were tested during this step of study – rises in frequencies in frequency components of sirens and falls in frequencies in frequency components of sirens.

These groups were tested for the normality of a distribution of results in said groups. The analysis was conducted in 3 steps – graphical method, Shapiro-Wilk [32] method and Lilliefors test [33]. Results of these tests had shown the lack of a normality of a distribution. Graph depicting said distribution for frequency fall is shown in Fig. 9.

Altogether from presented signals were obtained 18 results for each group. Their values are presented in Table 1.

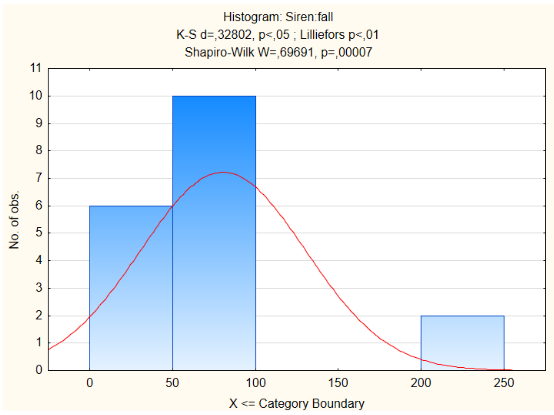

Fig. 9 Data distribution for fall in frequency components of siren.

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TABLE 1 OBTAINED RESULTS FOR SIRENS

Frequency rise, speed, Hz/sec	Frequency fall, speed, Hz/sec
148,69	71,03
148,60	70,71
163,15	208,08
163,12	208,04
110,79	39,75
110,79	43,54
228,02	76,32
220,71	76,53
120,58	40,11
120,66	38,95
244,26	87,26
244,49	87,26
104,97	49,75
85,96	48,76
254,91	80,14
228,70	81,54
88,41	52,75
167,22	88,09

Although usually Studends t-criterion is used in medical studies [34], this time it isn't possible due to distribution parameters. Via usage of a Mann-Whitney U Test [35] was estimated the presence of a statistically meaningful difference between the rise and fall of frequency components of the siren signal. Results of analysis are presented on Table 2.

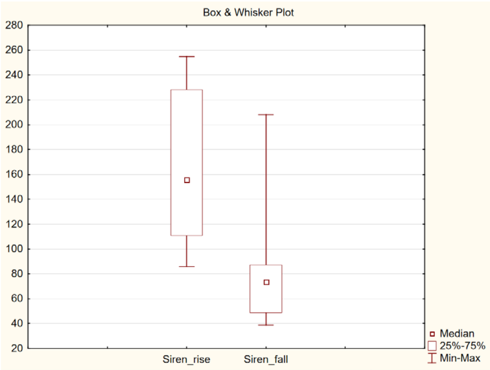

Fig. 10 Graphical group representation for siren

TABLE 2 RESULTS OF GROUP TESTING FOR DIFFERENCES

Mann-Whitney U Marked tests are significant at p <,05000						
Rank Sum Group 1	*Rank Sum Group 2*	*U*	*Z*	*p-value*	*Z adjusted*	*p-value*
468,0000	198,0000	27,00	4,255392	0,000021	4,255666	0,000021

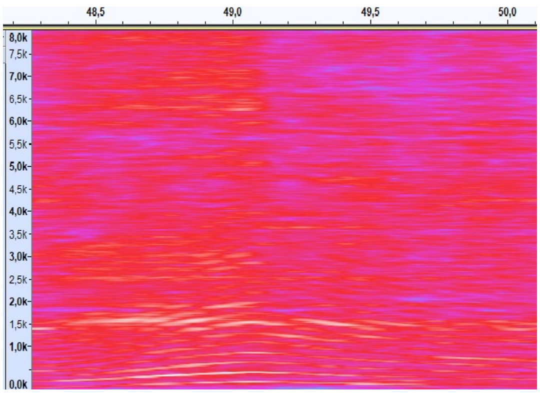

Fig. 11 Spectrogram of a fragment of sound of a passing bike

Graphical representation of differences between groups is shown on Fig. 10

B. Used motorbike signals

For traumatizing signal references motorbike movement signals were used. First one [36], subjectively alike to stress inducing one is present as a spectrogram on Fig. 11. In said signal was observed rise and fall of frequency, characteristically related to the Doppler effect in a bike that approaches the observer and passes by him.

Second one [37] also had frequency characteristics akin to the first one, obtained via the same method. Two result in said group were obtained from this fragment. Their combined results are shown in Table 3. Those data point are considered rise and fall groups, respectfully.

Also noteworthy is the fact that length of sound fragments for frequency change for motorbike was far shorter as it lacked constant fragment of frequency components. Average lengths of said components was 1.5 s.

TABLE 3 OBTAINED RESULTS FOR MOTORBIKES

Frequency rise, speed, Hz/sec	Frequency fall, speed, Hz/sec
154,28	60,63
198,49	47,56
154,38	47,64
144,97	41,91
157,55	42,09
153,43	44,39
147,28	47,27
133,87	52,84
216,46	55,02
129,25	51,19
151,26	40,24
151,42	40,30
172,43	43,45
143,92	64,92
149,95	119,99
180,09	150,17
117,59	182,11
323,89	90,38

It is possible to observe that demonstrated effects are akin to the Doppler effect [38], represented by formula (2):

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$$f' = f\left(\frac{c \pm v_0}{c \mp v_s}\right). \qquad (2)$$

For the formula shown above: f' – observed frequency, f – original frequency, c – speed of sound in the experiment medium, v_0 – velocity of observer, v_s – velocity of source. Using the presented formula we can see that for 1 kHz frequency component and for the speed of moving source up to 360 km/hour for approaching source frequency can change up to 1417 Hz and for departing down to 773 Hz, so calculated changes correspond with data in Table 2 and Table 3.

Another possible source of rise and fall of frequency components can be in change of rate of revolution per minute (RPM) of motorbike motor group. Example of relations between the RPM rate and frequency of sound can be seen in example [39].

Statistical analysis has shown that normal distribution of data is not present in rise and fall groups, as shown in Fig. 12. Usage of a groups of this size is possible due to large value differences in groups and was estimated possible in study [40].

C. *Difference calculations*

Differences between bikes and sirens were estimated via implementation of statistical analysis – search of statistically meaningful differences via non-parametric methods due to the nature of distribution in data groups.

For rise in frequency of a frequency component there was observed no statistically meaningful difference, results of a Mann-Whitney test are shown in Table 4.

Presentation of relation of two said groups is presented on Fig. 13.

Furthermore, the fall of frequency component also does not have said difference, what is shown in Table 5.

Generalization of obtained data is presented on Fig. 14, where box 1 is siren frequency rise speed, box 2 – bike frequency rise speed, box 3 is siren frequency fall speed, box 4 – bike frequency fall speed. Boxes on said picture correspond with data in aforementioned tables.

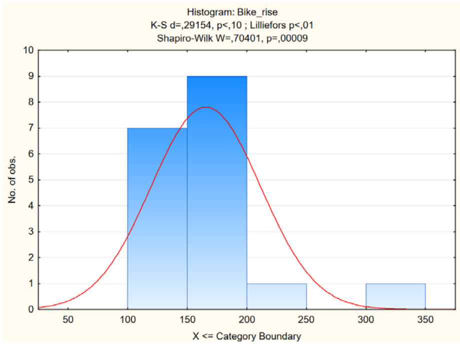

Fig. 12 Distribution of results in bike frequency change group

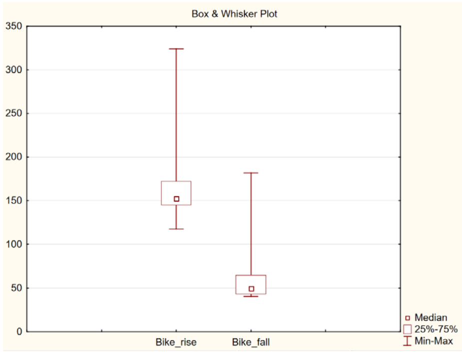

Fig. 13 Graphical group representation for bike

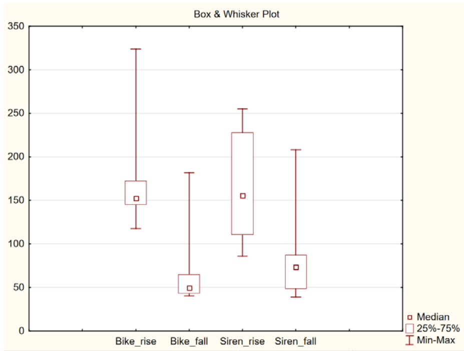

Fig. 14 Data group relations

TABLE 4 RESULTS OF GROUP TESTING FOR DIFFERENCES BETWEEN BIKES AND SIRENS, RISE OF FREQUENCY

Mann-Whitney U Test Marked tests are significant at p <,05000							
U	*Z*	*p-value*	*Z adjusted*	*p-value*	*Valid N Group 1*	*Valid N Group 2*	*2*1sided exact p*
155,00	0,206	0,837	0,206	0,837	18	18	0,839

TABLE 5 RESULTS OF GROUP TESTING FOR DIFFERENCES BETWEEN BIKES AND SIRENS, RISE OF FREQUENCY

Mann-Whitney U Test Marked tests are significant at p <,05000							
U	*Z*	*p-value*	*Z adjusted*	*p-value*	*Valid N Group 1*	*Valid N Group 2*	*2*1sided exact p*
129,00	-1,03	0,30	-1,03	0,30	18,00	18,00	0,31

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CONCLUSIONS

In this study a possibility of a rapid frequency change in frequency components of acoustical signal being the acting factor of growing stress levels in people.

Said stress levels are present due to frequent and unscheduled alarms due to current historical situation. Alarms can last for prolonged periods of time and make stress leave a lasting impact upon public health.

During the analysis of alarm signals via obtaining their spectrograms it was found that they have one major thing in common – rise and fall in frequencies of their frequency components (shown on spectrograms as clearly visible lines). Changes of frequency were presented as numbers of bumps upon otherwise straight frequency components.

Said changes in frequency can be characterized by the speed of change in them. For the rise of frequency, mean speed in the siren group was calculated as 164 Hz/second with standard deviation in group 58,35 Hz/second. Fall of frequency for the siren was 80 Hz/second. Character of sound in motorbike signals clearly represents the presence of the aforementioned Doppler effect.

For observed bike sounds (which were chosen to subjectively resemble sounds of the bike which resemble alert signals) there also were present said changes of frequency in frequency components. Character of sound in motorbike signals is most likely representing the presence of the aforementioned Doppler effect.

Apart from the Doppler effect the reason for frequency change in bike sound can be found in RPM rate rise due to increase in speed of said bike in time of acceleration and decrease of it during deceleration.

The experiment involved estimating the possibility of usage of parametric test criterions numerical values of measured parameters by matching the distribution in test groups to the normal distribution. To do this, the Shapiro-Wilk method, graphical analysis, and Lilliefors method were used. Statistical analysis itself was conducted via the non-parametric method — the Mann-Whitney test due to non-normal distribution.

For the bike, the speed rise of a frequency in frequency component had a mean value of 166 Hz/second and fall of frequency was estimated as 68 Hz/second.

Conducted analysis of obtained speed of frequency change had shown the presence of statistically meaningful difference in speed of frequency change for rise and fall of frequency component in siren group. For siren and bike there was observed the lack of statistically meaningful difference for rise and fall groups for siren and bike frequencies.

Also further investigation is needed to find out the proportion of the impact on stress level from the RPM growth of the motor of the motorbike during acceleration and the Doppler effect respectively.

CONTRIBUTION OF AUTHORS

Pareniuk D. — processing of experimental data; carrying out the calculations.

Pareniuk A. — formalization of work, analysis of literature.

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Оцінка діючого фактора стрессу від звуків мотоциклів

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***Анотація*—На сьогоднішній день у нашій країні особливу роль відіграють системи раннього оповіщення населення про загрози. Від початку повномасштабного вторгнення в Україну сигналізація стала частиною життя кожного мешканця країни. Загалом в Україні від 24 лютого 2022 року було оголошено близько 38 260 тривог. Лише у Києві з 24 лютого було подано 1055 сигналів тривоги. Загалом небезпека тривала 1209 годин 59 хвилин. Відомо, що саме ефективна комунікація з населенням у воєнний час є чудовою стратегією порятунку життів. Відомо, що від 35 до 45% зафіксованих втрат серед цивільного населення можна уникнути шляхом реагування на оголошені тривоги.**

В той самий час відомо, що звуки сигналів повітряної тривоги рятують життя, вони в свою чергу є джерелом стресу. Відомо, що люди можуть відносити не пов'язані зі стресом фактори до причин його дії і відчувати ті самі емоції без прямої дії травмуючих факторів. Таким фактором можуть бути звуки повсякденного життя, а саме – звук мотоциклу, що прискорюючись проїжджає повз спостерігача. Такі звукові сигнали часто можна почути у багатьох українських містах, зокрема у столиці.

Окремо варто вказати негативні фактори дії стресу на організм людини: це можуть бути зниження імунної функції, погіршення розумової діяльності, зниження ефективності вакцинації та інші. Томі існує необхідність знизити частоту експозицій людини до факторів, що викликають стрес.

Для цього в даному дослідженні було досліджено сигнали сирен із різних країн – України, США, Німеччини, Швейцарії та Франції з метою пошуку подібностей у них. Такою подібністю є сукупність послідовних підвищень та падінь частот складових сигналів досліджених сирен. Названі складові як правило є їх тональними компонентами. Ідентичний ефект було виявлено також для сигналів мотоциклів, що рухаються повз спостерігача. Для наведених сигналів сирен та мотоциклів було визначено швидкість падіння та росту частоти складових сигналів. Було обрано цю величину як діагностичний параметр для аналізу звуків мотоциклів, котрі прискорюючись проїжджають повз спостерігача. Як можливі причини виникнення такого ефекту у мотоциклів можна назвати ефект Допплера та підвищення частоти обертів двигуна під час прискорення та її зниження під час зменшення інтенсивності роботи двигуна після прискорення.

У приведеній статті також наведено результати статистичної обробки отриманих значень швидкості зміни частоти для обох груп сигналів — сирен та звуків проїжджаючих мотоциклів. Для ділянки росту частоти середня швидкість у групі сирен була розрахована як 164 Гц/с, ділянка зниження частоти компонентів мала швидкість у цій групі 80 Гц/с. Для мотоцикла швидкість зростання частоти мала середнє значення 166 Гц/с, а середню швидкість зниження частоти було оцінено як 67 Гц/с. Отримані значення швидкостей були згруповані відповідно до їх походження. Після цього із використанням графічного методу порівняння із нормальним розподілом, використанням методів Шапіро-Уілка та Ліллієфорса було визначено невідповідність отриманих результатів нормальному законові розподілу. Сам статистичний аналіз було виконано із використанням непараметричного методу – тесту Манна-Уітні. Виконаний аналіз показав наявність статистично значимої різниці між швидкостями падіння та росту частоти окремих складових у сигналах сирен. Така ж різниця була виявлена між швидкостями падіння частоти для груп сирен та мотоциклів. Однак при порівнянні швидкостей росту частоти окремих складових сигналів мотоциклів та сирен статистично значимої різниці виявлено не було, що може вказувати саме на те, що ріст частот окремих складових звуків руху мотоциклів, які проїжджають повз спостерігача, може бути діючим фактором, що викликає підвищення рівня стресу у людини.

Ключові слова —індукуючі стрес звуки, сирени, частотний аналіз, спектрограма, непараметричний тест.