IMPACT OF INFRASOUND NOISE AND VIBRATIONS ON PSYCHOPHYSICAL FITNESS OF PROFESSIONAL DRIVERS

Jan Radosz[1]

[1]Central Institute for Labour Protection – National Research Institute
Czerniakowska 16, 00-701 Warsaw, Poland
jarad@ciop.pl

Abstract
The literature shows that infrasonic noise in road vehicles often exceeds the admissible values due to annoyance. In the case of mechanical vibrations occupational risk is assessed as average. Although these factors do not exceed values which can be harmful, they can influence the psychophysical functions. Study involved a group of 30 drivers with varying age and experience in driving. The study was conducted in laboratory conditions. Infrasonic noise and mechanical vibrations was recreated from measurements at drivers' workplaces. The aim of the pilot study was to verify the test method for different conditions of exposure to physical agents. The paper presents the results of six tests evaluating psychomotor performance in the field of psychometrics and cognitive processes (evaluating the reaction time, attention and concentration , and anticipation of movement) in relation to the features considered essential for safe driving.

Keywords: infrasounds, noise, drivers, annoyance, vibration.

PACS no. 43.64.+r, 43.50.+y

1 Introduction

Infrasound noise is defined as a type of noise whose spectrum is contained within the frequency range of 1 to 20 Hz [1]. Contrary to popular beliefs, infrasound is not inaudible but perceived by the body via a specific aural route (mainly by the organ of hearing). Its audibility depends on the sound pressure level. Infrasound noise is a physical factor commonly found in the work environment of drivers, especially drivers of buses and heavy goods vehicles. Research carried out by Polish centres has shown that the highest levels of infrasound are to be noted in city buses, reaching as much as 114 dB (G)[1] [5]. These significantly exceed the nuisance criterion values as defined by the Polish Standard PN-N-01338 [1], amounting to 102 dB (G).
Literature reports indicate that the dominant effect of the impact of infrasound and low frequency sound on the human body during occupational and non-occupational exposure is the nuisance effect, occurring even with low hearing threshold exceedances [6].

[1] Infrasound noise is tested using sound level meters and the G-weighting curve, which reflects the human perception of infrasound. Do not confuse or relate the dB value (G) to noise value in the audible range dB (A).

The effects of noise with a frequency of 16 Hz at a level of 10 dB above the hearing threshold were observed by Landström and Byström [4]. Exposure to noise caused fatigue and disturbance in wakefulness. Similar results were obtained by Yamazaki and Tokita [5]. According to them, infrasound causes fatigue, depression, stress and sleepiness. Other studies by Danielsson and Landström [6] demonstrate the effect of sounds with frequencies of 6, 12 and 16 Hz and levels of, respectively, 95, 110 and 125 dB on the circulatory system. Systolic blood pressure increase and diastolic blood pressure decrease with no change in the pulse rate have been demonstrated. The biggest symptoms were observed for the frequency of 16 Hz and these symptoms were intensified under the influence of increasing sound level and completely disappeared after cessation of exposure. Studies show that the symptoms discussed are transient and reversible following removal of the infrasound source. When the sound pressure levels exceed 140–150 dB, infrasound can cause permanent, damaging changes to the body [7]. Resonance of structures of internal body organs may occur.

Excessive long-term exposure to infrasound and low-frequency sound of high intensity (with levels above 90–110 dB) can cause many ailments, including abnormal functioning of nervous, circulatory, respiratory and digestive systems, which is referred to by some researchers as vibroacoustic disease (VAD) [8].

Some studies suggest that infrasound with a frequency of 2 to 20 Hz and a sound pressure level of 115–120 dB can extend response time by 30 to 40% and contribute to the emergence of symptoms of sleepiness [9, 10, 11, 12]. Therefore CIOP-PIB has undertaken research aimed at assessing the impact of infrasound noise on psychomotor performance of city bus drivers. The article presents results of tests in which 5 psychological tests were used to assess psychophysical fitness with respect to psychomotor performance and cognitive processes in relation to certain features considered essential for safe driving.

2 Measurement of infrasound noise in city buses

The purpose of infrasound noise measurements was to record infrasound noise levels and spectrum under real operating conditions of city buses and recreate the noise in a laboratory environment. The measurements were carried out in accordance with the PN-N-01338 standard [1]. Class 1 measuring equipment was used (SVAN 945A sound level meter). The measuring points were in the driver's cab. The duration of each measurement was approx. 30 min. during regular service travel with passengers.

Figure 1 shows the results of equivalent G-weighted and A-weighted sound level during travel. Equivalent G-weighted sound levels ranged from 103.8 dB to 111.2 dB and depended both on the type of vehicle and the road surface on which the vehicle moved.

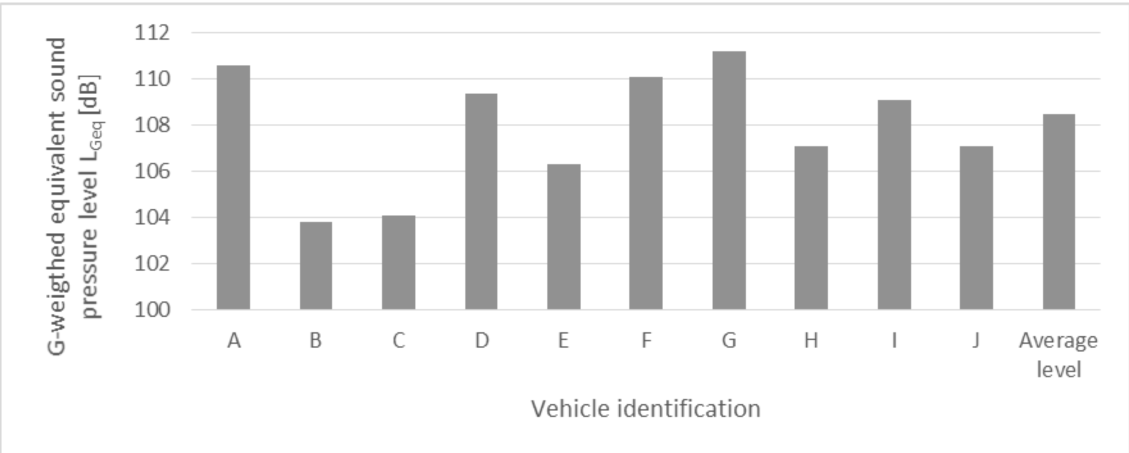

Figure 1 – Results of equivalent G-weighted and A-weighted sound level during travel

3 Test method and test stand

The purpose of the test was to assess the impact of infrasound noise on psychophysical fitness of city bus drivers. The following 5 psychological tests were used to assess psychophysical fitness:

I. Response to road event test (pedestrians, cyclists or animals suddenly entering the road) during simulated driving (STD Simulator) – the task of the tested person was to stop the vehicle when an event occurs. The test involved 6 travels lasting approx. 10 minutes. Test results were evaluated with the use of average response time to an event for all the travels combined.

II. Simple response time to light test (RT-L) – the task of person tested was to press the appropriate pedal when the tester light switches on. Average response time was used to evaluate test results. The test lasted 8 minutes.

III. Simple response time to sound test (RT-L) – the task of person tested was to press the appropriate pedal when a tester sound is activated. Average response time was used to evaluate test results. The test lasted 8 minutes.

IV. Attention and concentration test (COG) – the task of the person tested was to observe and compare changing pairs of figures. Average time needed to correctly reject pairs of (non-compatible) figures was used for evaluation of test results. The test lasted 10 minutes.

V. Time and motion anticipation test (ZBA) – the task of the person tested was to observe a ball moving on the screen and predict the time after which the ball reaches a specified location once it disappears. Average deviation time from the actual moment of the moving ball reaching the specified location was used for evaluation of test results. The test lasted 10 minutes.

These tested performance items are directly related to a driver's safe driving behaviour in traffic, because they impact the assessment of a traffic situation, the ability to take decisions appropriate for the situation as well as efficient and safe execution of manoeuvres.

Preparatory and introductory activities lasted approx. 30 minutes. The total test duration was approx. 2-2,5 hour for each of the two variants of exposure to infrasound noise (without any noise and with noise).

A test stand was developed and built for these tests, including a seat with a steering wheel and pedals, a projector and screen with a width of 2.2 m, sources of infrasound noise with amplifiers, B&K PULSE 3650C measurement system, Rigol DG2041A signal generator, MCZR/ATB 1.0 response time meter and computer software used for testing (Vienna Test System, SDT Simulator).

Infrasound noise occurring in real conditions of city bus driving was recreated in the laboratory environment to achieve a similar average level – 108 dB (G).

The test was carried out with the participation of 30 drivers aged 30–40, holding a driver's license for at least 5 years.

The following statistical tests were used for the analysis of results:

- Kruskal-Wallis test to compare the distribution of variables,
- Student's t-test for dependent samples to compare averages,
- Wilcoxon signed-rank test for paired observations to verify the equality of medians.

4 Test results

The comparison of the tests of response to a road event tests during simulated driving (STD Simulator) showed a slight shortening (by 0.6% and 0.3%) in average response time in case of exposure to infrasound noise and exposure to vibration when compared with no exposure. Statistical tests did not show a statistically significant variation. In case of simultaneous exposure to infrasound noise and vibration observed shortening of the average response time of 2.3% was observed when compared with no exposure (Fig 2).

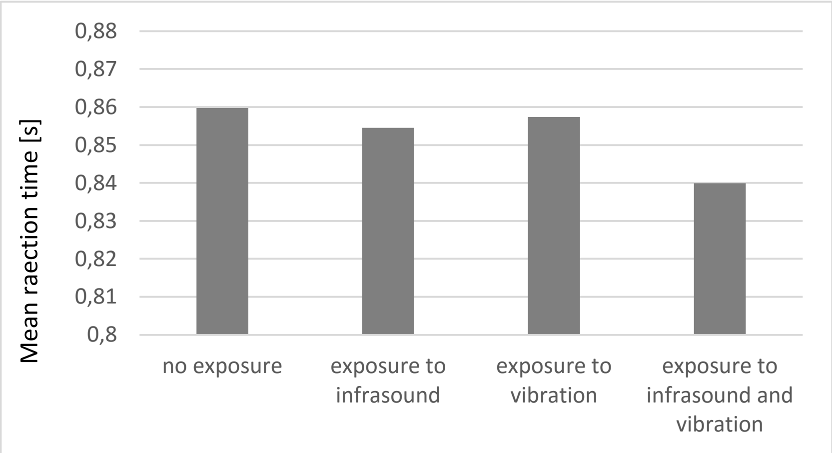

Figure 2 – Comparison of test results carried out with the use of the STD Simulator
(no statistically significant variation at $p < .05$)

In case of exposure to vibration and simultaneous exposure to infrasound noise and vibration slight increase of the mean reaction time (respectively 0.9% and 0.7%) was observed when compared with no exposure (Fig. 3). Mean reaction time during exposure to infrasound noise was reduced by 2% (in relation to no exposure). However statistical tests did not show a statistically significant variation.

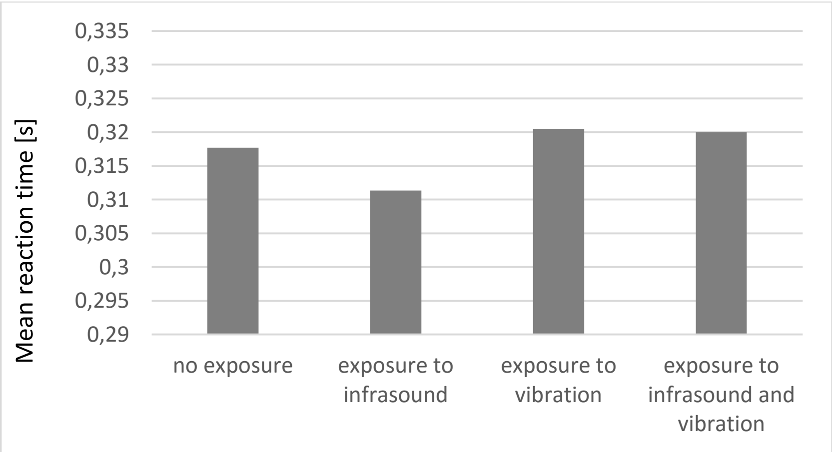

Figure 3 – Comparison of test results for simple response to light RT-L
(no statistically significant variation at $p < .05$)

In case of exposure to vibration and the simultaneous exposure to infrasound and vibration lengthening of the mean reaction time (respectively 4.9% and 4.4%) was observed when compared with no exposure (Fig. 4). However statistical tests did not show a statistically significant variation.

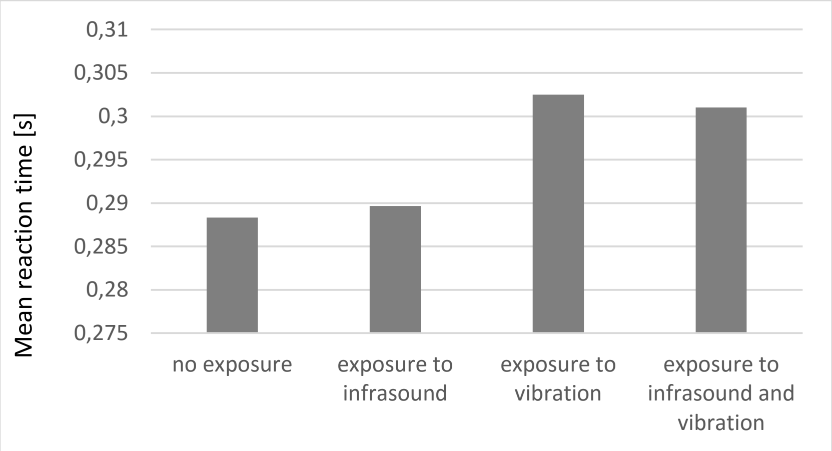

Figure 4 – Comparison of test results for simple response to sound RT-S
(no statistically significant variation at $p < .05$)

The comparison of the attention and concentration tests (Fig. 5) under conditions of no infrasound noise and under conditions of infrasound noise showed some increase in the time during exposure to infrasound noise (8,1%). However statistical tests did not show a statistically significant variation.

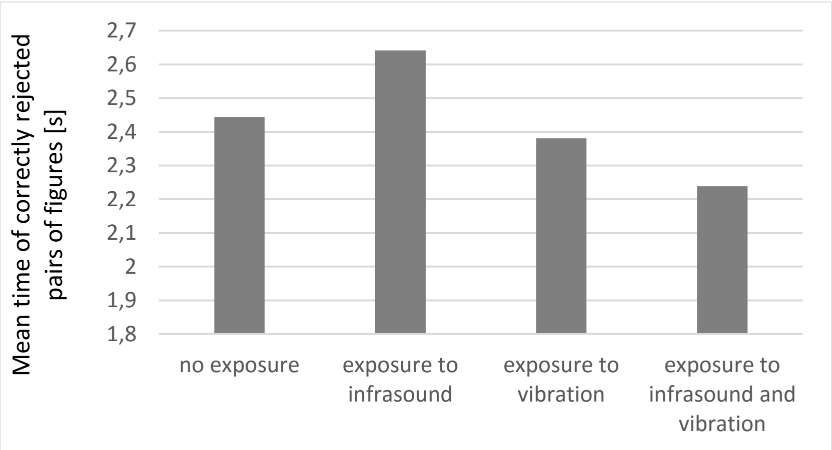

Figure 5 – Comparison of attention and concentration test results COG
(no statistically significant variation at $p < .05$)

The comparison of the time and motion anticipation tests (Fig. 6) under conditions of no infrasound noise and under conditions of infrasound noise showed a slight reduction of average time deviation (14%) during exposure to infrasound noise. This was confirmed by statistical tests, which showed statistically significant variation.

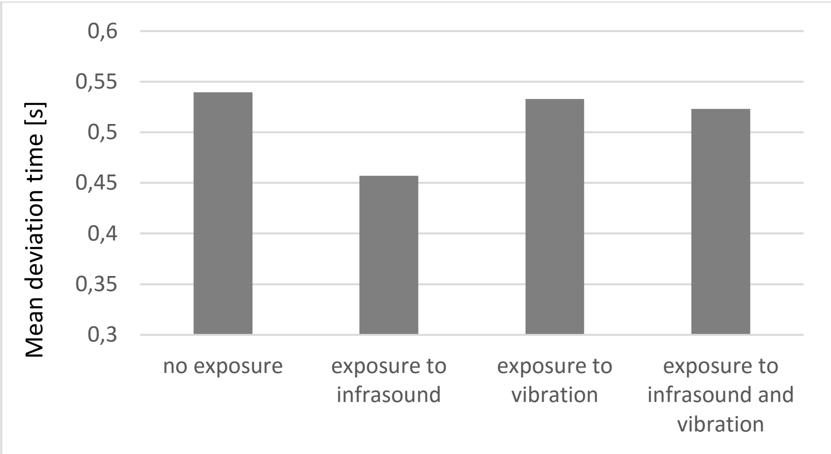

Figure 6 – Comparison of time and motion anticipation test results ZBA (statistically significant variation at $p < .05$)

5 Conclusions

The results of infrasound noise measurements have confirmed the reports of high levels of this physical factor at work stations of city bus drivers. The infrasound noise levels during regular service travel with passengers ranged from 103.8 dB (G) to 111.2 dB (G) and were dependent both on the type of vehicle and the road surface on which the vehicle moved. The results of measurements were used to test the impact of infrasound noise on psychomotor performance of city bus drivers. Five psychological tests were selected for this purpose to assess the psychophysical fitness with respect to psychomotor performance and cognitive processes (evaluation of response time, attention and concentration and time and motion anticipation) in relation to certain features considered essential for safe driving and an appropriate test stand was developed to simulate the infrasound noise and vibration occurring in city buses. The results of tests on the effects of infrasound noise an vibration on psychomotor performance of drivers in most cases did not show any statistically significant differences between the occurrence of these factors and its lack for all tests. However, we have noted some changes in the average time needed to correctly reject pairs of figures in the attention and concentration test (increase of 8,1%) and in the average time deviations of the time and motion anticipation test (decrease of 14%) in case of infrasound noise exposure.

Test results do not clearly indicate the negative impact of infrasound noise an vibration on drivers in the context of safe behaviour in traffic, but the trends observed suggest the need to continue research with even longer exposure to these factors.

Acknowledgements

This publication has been based on the results of the third stage of the program "Safety and working conditions improvement", co-funded in the years 2014-2016 within the capacity of the governmental services by the Ministry of Labour and Social Policy. The main coordinator: Central Institute for Labour Protection – National Research Institute.

References

[1] PN-N-01338: 2010 Acoustics. Measurement and assessment of infrasound noise at workstations [Polish: Akustyka. Pomiar i ocena hałasu infradźwiękowego na stanowiskach pracy].

[2] Kaczmarska A., Augustyńska D. (2005-2007): Assesment of occupational risks associated with exposure of drivers of road transport vehicles on infrasound noise, long-term program entitled "Adaptation of working conditions in Poland to European Union standards, Part B: The implementation of tasks for state services [Polish: Badania i ocena ryzyka zawodowego związanego z narażeniem kierowców środków transportu drogowego na hałas infradźwiękowy, Program wieloletni „Dostosowanie warunków pracy w Polsce do standardów Unii Europejskiej" Część B: Program realizacji zadań w zakresie służb państwowych]

[3] Pawlaczyk-Łuszczyńska (2010) Rating low frequency noise disturbance in the work environment and its impact on mental function - postdoctoral thesis IMP [Polish: Ocena uciążliwości Hałasu niskoczęstotliwościowego w środowisku pracy oraz jego wpływ na funkcje umysłowe - rozprawa habilitacyjne IMP]

[4] Landstrom, U., and M. Bystrom (1984) Infrasonic threshold levels of physiological effects. J. Low Freq. Noise Vib. 3(4):167-173.

[5] Yamazaki K., Tokita Y. (1984) Effects of infra and low frequency sound on sleep stage. Proceedings of Internoise 929-932,

[6] Danielsson, A., and U. Landstrom (1985) Blood pressure changes in man during infrasonic exposure. An experimental study. Acta Med. Scand. 217(5):531-535.

[7] Moller, H. (1984) Physiological and psychological effects of infrasound on humans. J. Low Freq. Noise Vib. 3(1):1-16.

[8] Alves-Pereira M., Castelo Branco N. (2007) Vibroacoutic disease: biological effects of infrasound and low frequency noise explained by mechanotransduction cellular signalling Progress in Biophysics and Molecular Biology 93, 256-279

[9] Evans, Margaret J. W. Tempest (1972) Some effects of infrasonic noise in transportation Journal of Sound and Vibration Volume 22, Issue 1, 8 May, Pages 19–24

[10] Harris, C.S., and D.L. Johnson. (1978) Effects of infrasound on cognitive performance. Aviat. Space Environ. Med. 49(4):582-586.

[11] Holmberg K., Landstrome U., Sorderberg L., Kjellberg A., Tesarz M. (1996) Hygienic assessment of low frequency noise annoyance in working environments J Low freq nosie Vibration, 15.1, 7-15

[12] Ising, H. (1980) Psychological, ergonomical, and physiological effects of long-term exposure to infrasound and audiosound. Noise Vib. Bull. 54:168-174.

[13] J. Radosz (2014) A pilot study of psychomotor performance of bus drivers [Polish: Wpływ hałasu infradźwiękowego na sprawność psychofizyczną kierowców autobusów miejskich], Autobusy - Technika, Eksploatacja, Systemy Transportowe 11, p. 8-12