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Effects of vibration exposure on professional drivers: a field test for quantifying visual and cognitive performance

N. Costa[a,*], P. M. Arezes[a] and R. B. Melo[b]
[a] *Department of Production and Systems, School of Engineering, University of Minho, Campus of Azurém, 4800-058 Guimarães, Portugal.*
[b] *Department of Ergonomics, Faculty of Human Kinetics, Technical University of Lisbon, Estrada da Costa, 1499-002 Cruz Quebrada, Lisbon, Portugal.*

Abstract. Effects of whole-body vibration (WBV) exposure on professional drivers were predicted using a 45 subjects sample of healthy volunteers from both genders. These volunteers preformed a visual/motor accuracy evaluation test, the 'omega test', inside a vehicle (van) under three different WBV exposure conditions, van halted, van performing a circuit on asphalt, and on cobblestone. WBV levels of the stated conditions were statistically different and impairment upon subjects' performance was found. The statistical significant difference encountered between the subjects performance under the two whole-body vibration profiles (asphalt and cobblestone), seems to indicate that the vibration levels also represent a variable to be taken under consideration. No gender related difference was found.

Keywords: Whole-body vibration, acuity, aptitude, performance.

1. Introduction

Whole-body vibration (WBV) seems to be a well-studied subject considering its effects on the driver/operator's health. Studies on the effects of vibration on tracking performance first began in the 1960's. Almost at the same time, physiological parameters were measured as secondary indicators of performance. Harris and Shoenberger (1966), for example, investigated the effects of vibration on three different perceptual tasks: target identification, probability monitoring and warning-lights monitoring [4]. Since the 1970's several studies on the effects of vibration on visual acuity have also been reported [15].

The need to comparatively evaluate the cognitive performance of test subjects exposed to WBV arises based on bibliographic evidence attesting various effects of exposure to WBV in addition to the effects on operator's health. One of the references that should be highlighted is the article published in 1994 by Griffin & Hayward. In this article, the authors investigate the effects of WBV in its horizontal component (X and Y axes) on the ability to read a text from a newspaper. The authors used as a variable the number of syllables read on a thirty seconds time frame. The main conclusions point to a statistically significant reduction in reading speed in the range 3.15 - 5 Hz, crossed with acceleration values of 1.0 and 1.25 m/s^2, with the most significant reduction to occur at a frequency of 4 Hz, for same values of acceleration [3].

Recently, Lin et al. (2008), demonstrated that the identification of numerical digits on computer display was negatively affected by vibration and the effect is dependent on the magnitude of vibration frequency, amplitude, and even direction, and also by font size and number of displayed digits. The frequency, amplitude, and direction of vibration had also significant effect on accuracy of the task [9].

* Corresponding author. E-mail: ncosta@dps.uminho.pt. Telephone:+351510540 Fax:+351253510343.

Even though humans visual system discount the contribution of eye movements to retinal image motion, Peli & García-Pérez (2003) found that some vibration frequencies can create illusory perception of motion [14].

The selected bibliography had an interesting proposal for the synthetic model of the components involved in the effects of human exposed to whole-body vibrations. Kubo, et al. (2001) assumed that the vibration characteristics of the human body can be explained by three sets of reactions, when the human body is exposed: i) The reaction expressed by the physical transfer of vibrations from one body part to any other part, for example, in a person sitting on a chair that vibrates, transferring the vibration to the upper limbs; ii) The physiological reaction that is manifested by changes in blood pressure, heart rate, etc.; iii) The psychological reaction illustrated by the manifestation of various symptoms induced by vibration, such as irritation, loss of patience, attention loss, etc. [8].

Another physiological reaction to WBV exposure was investigated by Ishitake et al. (2002) and disruptions of the normal rhythm of gastric motility were found [6].

However, almost all of the experimental studies were performed under strictly controlled laboratory conditions and with a well-defined vibration exposure intensity and/or frequency.

The aim of this study was to evaluate the vibration effects on cognitive and visual performance using field tests. With this purpose and to, hopefully, achieve innovative results, this study included tests performed in a 'real' performing context.

2. Methodology

In order to test the aforementioned effects in a 'real' exposure environment, the back of a 2.5 ton van (Citroen Jumper 2.5D) was modified with the inclusion of two car seats and a platform to accommodate the applied tests, namely, the 'omega test'.

The procedure for assessing subjects' visual and cognitive performance was developed from previous validation tests. From these tests it was possible to identify some drawbacks to their application and, accordingly, the current test procedures were improved to overcome these difficulties. According to the identified needs for the standardization and homogeneity of the applied tests, subjects receive no other stimuli than the information presented on the test screen. The movement of the van was performed in a closed circuit for each test and with a vehicle speed up to 10 Km/h. This circuit has two different pavements: one of asphalt and one of cobblestone. This feature allowed performing the 'omega test' under three different conditions: (i) with the van halted, (ii) with the van performing a circuit on asphalt, and (iii) on cobblestone.

The 'omega test' instrumentation was designed to examine the precision in the handling of mechanisms and careful attention. The test tool/instrument is equipped with two knobs that move a pointer along a sinuous line. This should be done without touching the edge. Figure 1 presents de sinuous line with the pointer path. In the administration of the 'omega test' instructions were given to the test subject, according to the protocol mentioned in the application manual [1].

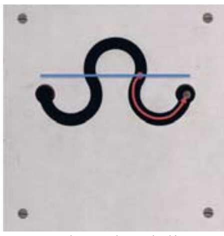

Figure 1 - Sinuous omega shaped path line, with pointer placed at the start/stop, on the right.

Every time the pointer touch an edge, both number of errors (NE) and total error duration (DTE) are recorded by the CTSS recording battery. The error duration is the time elapsed between the occurrence of the error and its correction by taking the pointer away from the edge. Total time (TT) to perform the task was also registered. The order of the test conditions was randomized in order to minimize the potential skill/proficiency effects, which may occur when the subjects become more familiarized with the test.

The sample subjects were randomly selected through personally addressed invitations to population that attends University of Minho, at Azurém campus. This sample included students from the first, second and third cycles of higher education. i.e., Degree, MSc. and PhD. students, teachers from different departments of the School of Engineering and also some staff from the Administrative and Social Services of the University. The considered sample was composed of 45 volunteers, from both genders, with ages between 21 and 62 years old (mean of 33.1±10 years old). All the selected subjects should have more than one year of driving experience (mean of 13.2±9.8 years of experience).

3. Main results

The vibration R.M.S. values for each of the test conditions were measured according to the NP ISO 2631-1:2007 [5]. Acceleration values ($a_{wk(Z)}$) for asphalt ranged from 0.17-0.23 m/s^2 (mean of 0.20±0.01 m/s^2) and 0.43-0.68 m/s^2 (mean of 0.54±0.05 m/s^2) for cobblestone. Statistical analysis of the mean acceleration values for the three axes (x, y and z), performed with IBM SPSS Statistics (version 19) revealed significant differences between the van performing a circuit on asphalt, and on cobblestone (p<0,001), this way insuring that the three exposure conditions where indeed different (van halted, van performing a circuit on asphalt, and on cobblestone).

The 'omega test' grades subjects according to their final result, with subjects being classified according to the total error duration (DTE). Table 1 presents the descriptive statistics that were obtained from the application of the referred test.

The results obtained in the current study seem to point out an increasing number of errors (NE), total error duration (DTE) and total time to undertake the test (TT) as the vibration exposure levels increases, when compared to the halted van condition.

Table 1

Descriptive statistics (in seconds) of the main results.

Variable	Condition	N	Mean	Std. Deviation
NE	Halted	45	5.56	6.31
	Asphalt	45	13.56	11.93
	Cobblestone	45	27.20	15.88
DTE	Halted	45	13.76	22.51
	Asphalt	45	34.56	37.02
	Cobblestone	45	103.89	146.09
TT	Halted	45	41.82	19.49
	Asphalt	45	45.29	20.25
	Cobblestone	45	51.00	25.47

In order to evaluate de statistical significance of the obtained results, Friedman Non Parametric Test was undertaken in IBM SPSS Statistics (version 19). The obtained results are presented on table 2.

In table 2, the three different exposure conditions were crossed and statistical significant differences were found between halted and asphalt vibration profile, and between halted and cobblestone vibration profile. These results allow to state that WBV impairs performance on the 'omega test'. Since the 'omega test' is manly a visual/motor accuracy evaluation tool, one can reformulate the prior statement and state that it seems that evidences of visual/motor impairment were found as a result of WBV exposure.

Table 2

Friedman Test statistics for total error duration (DTE) exposure conditions.

Difference	Chi-Square	*p*
Halted *versus* Asphalt	24.381	< 0.001
Halted *versus* Cobblestone	36.364	< 0.001
Asphalt *versus* Cobblestone	18.689	< 0.001

The statistical significant difference encountered between the subjects performance under the two WBV profiles (asphalt and cobblestone), seems to indicate that the vibration levels also represent a variable to be taken under consideration. Subjects more than doubled their time to correct their errors (DTE). Curiously, the total time to undertake the test (TT) was very similar, nevertheless, statistical significance was encountered in the difference (p<0.001).

If the 45 subjects sample is divided by the gender of the participants, DTE differences still persist and are statistically significant. Table 3 resumes the results for the gender comparison.

Table 3

Friedman Test statistics for total error duration (DTE) exposure conditions and for each gender.

	Chi-Square	*p*	Chi-Square	*p*
	Male (N=25)		*Female (N=20)*	
Halted *versus* Asphalt	9.783	0.002	15.211	<0.001
Halted *versus* Cobblestone	25.000	<0.001	11.842	0.001
Asphalt *versus* Cobblestone	11.560	0.001	7.200	0.007

Similar results were reported by Ljungberg & Nelly over three different published papers. These authors first began to examine the effects of noise and WBV, combined or isolated, on cognitive performance. Although these authors did not found significant changes in reaction times, participants rated combined exposure as more annoying than isolated exposure [10]. An after exposure task was proposed by the authors in order to evaluate subjects' cognitive after-effects. Performance degradation was revealed in the attention task after exposure to vibration [11]. Further physiological reactions were investigated, namely the effects on saliva cortisol levels, a biological stress marker. The obtained results showed no substantially effect on the physiological stress, as measured by saliva cortisol [12].

Newell & Mansfield (2008), on their work to evaluate the influence of exposure to WBV in conjunction with hazardous working postures on the performance of a task, designed a methodology to evaluate the reaction time between visual stimulus and motor execution. The task was carried out in five work postures and involved the presentation of directional arrows in random order and intervals, on a monitor located 1.1 meters away from the subject, at which the subjects responded by pressing the arrow on a keyboard equivalent. The results obtained by those authors demonstrate that exposure to WBV and posture negatively influenced the reaction time of the test subjects. They also found that the reaction time was significantly longer when the subjects performed the task without the chair armrest. The percentage of correct answers was, likewise, evaluated by the authors, having found a significant increase in the number of errors. By its turn, posture did not reveal significant contribution in increasing the number of errors [13].

A positive relationship between the change in heart rate and exposure to WBV were also documented by Jiao et al. (2004). These authors also reported subjective symptoms of fatigue, namely fourteen subjective symptoms of fatigue evaluated by the test subjects. Four of them proved to be significantly statistically affected by WBV, in particular the increase of physical tiredness, desire to lie down, stiff shoulders and lack of spirit [7].

4. Conclusions

Evidence of visual/motor impairment was found as a result of whole-body vibration exposure.

The statistical significant differences encountered between the subjects performance under the two WBV profiles (asphalt and cobblestone) seem to indicate that the vibration exposure levels in moving vehicles also represent a variable to be taken under consideration.

No evidence was found showing that the impairment on performance is related with the subjects' gender.

It is expected that the obtained results will help at demonstrating that there is a visual and cognitive impairment resulting from the exposure to WBV in vehicles. Hopefully, these data may be used to improve the characteristics of the vehicles, hence reducing the corresponding adverse effects and, consequently, improving the working conditions of those workers that use vehicles in their job.

References

[1] EAP. (1975). Safety Batterie (Éditions Scientifiques ed.). Issy-Les-Moulineaux, France.

[2] Griefahn, B., Bröde, P., & Jaschinski, W. (2000). Contrast thresholds and fixation disparaty during 5-Hz sinusoidal single- and dual-axis (vertical and lateral) whole-body vibration. Ergonomics, 43(3), 317-332.

[3] Griffin, M. J., & Hayward, R. A. (1994). Effects of horizontal whole-body vibration on reading. Applied Ergonomics, 25(3), 165-169.

[4] Harris, C.S., Shoenberger, R.W., (1966). Effects of frequency of vibration on human performance. Journal of Engineering Psychology, 5(1): 1-15.

[5] IPQ, (2007). NP ISO 2631-1:2007, Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 1: General requirements. Instituto Português da Qualidade, Caparica, Portugal.

[6] Ishitake, T., Miyazaki, Y., Noguchi, R., Ando, H., & Matoba, T. (2002). Evaluation of frequency weighting (ISO 2631-1) for acute effects of whole-body vibration on gastric motility. Journal of Sound and Vibration, 253(1), 31-36.

[7] Jiao, K., Li, Z., Chen, M., Wang, C., & Qi, S. (2004). Effect of different vibration frequencies on heart rate variability and driving fatigue in healthy drivers. International Archives of Occupational and Environmental Health, 77(3), 205-212.

[8] Kubo, M., Terauchi, F., Aoki, H., & Matsuoka, Y. (2001). An investigation into a synthetic vibration model for humans: An investigation into a mechanical vibration human model constructed according to the relations between the physical, psychological and physiological reactions of humans exposed to vibration. International Journal of Industrial Ergonomics, 27(4), 219-232.

[9] Lin, C. J., Hsieh, Y.-H., Chen, H.-C., & Chen, J. C. (2008). Visual performance and fatigue in reading vibrating numeric displays. Displays, 29(4), 386-392.

[10] Ljungberg, J., Neely, G., & Lundström, R. (2004). Cognitive performance and subjective experience during combined exposures to whole-body vibration and noise. International Archives of Occupational and Environmental Health, 77(3), 217-221.

[11] Ljungberg, J. K., & Neely, G. (2007a). Cognitive After-effects of Vibration and Noise Exposure and the Role of Subjective Noise Sensitivity. Journal of Occupational Health, 49, 6.

[12] Ljungberg, J. K., & Neely, G. (2007b). Stress, subjective experience and cognitive performance during exposure to noise and vibration. Journal of Environmental Psychology, 27(1), 44-54.

[13] Newell, G. S., & Mansfield, N. J. (2008). Evaluation of reaction time performance and subjective workload during whole-body vibration exposure while seated in upright and twisted postures with and without armrests. International Journal of Industrial Ergonomics, 38(5-6), 499-508.

[14] Peli, E., & García-Pérez, M. A. (2003). Motion perception during involuntary eye vibration. Experimental Brain Research, 149(4), 431-438.

[15] Shoenberger, R., Harris, C.S., (1971). Psychophysical assessment of whole-body vibration. Human Factors, 13: 41-50. D.F. Pilkey, Happy conservation laws, in: Neural Stresses, J. Frost, ed., Controlled Press, Georgia, 1995, pp. 332–391.