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# The effects of combined exposure to road traffic noise and whole body vibration on types of attention among men

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**Keywords:** Exposure; road traffic noise; whole body vibration; cognitive; attention

## Abstract

***Background:*** *Noise and vibration are considered as harmful physical agents in the environment which have adverse effects on cognitive performance. One of the occupations at risk is driving, where there is a possibility of simultaneous exposure to road traffic noise and whole body vibration (WBV) transferred through the vehicle. This study aims to assess the effects of single and combined exposure to road traffic noise and WBV on different types of attention in men.* ***Methods:*** *The experiment was conducted on 24 men in 4 steps, executed on each participant inside an acoustic room. After recording a number of various attention scores at background conditions (27 dBA noise, no vibration) the participants were given single and combined exposure to noise levels at 55 and 85 dBA and vibration magnitude of 0.65 and 0.95 m/s² r.m.s.* ***Results:*** *As for combined exposure to noise and vibration, increasing vibration acceleration and noise levels at the same time compared to background condition caused a rise in the score of all visual attention types among groups exposed to low vibration acceleration and those exposed to medium acceleration and low noise. Nevertheless, when noise level and vibration acceleration is increased at the same time compared to background, auditory attention type scores mostly fell among groups with similar vibration accelerations.* ***Conclusions:*** *Overall, single and combined exposure to environmental stressors under investigation had a predominantly negative effect on auditory attention while the effects on visual attention were inconclusive. Definitive conclusions however require further systematic and comprehensive experiments.*

## Introduction

Currently, noise pollution is recognized as a widespread problem for the quality of life in urban areas throughout the world (1). Vehicular traffic noise is the most important source of environmental noise pollution within urban areas (2). Road traffic noise exposure can have negative mental and physical effects and may cause disruptions in daily activities such as annoyance, cardiovascular disorders

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and sleep disturbances and cognitive performance (3-5). Disruption of cognitive performance causes changes in comprehension, the speed of information processing and attention (3, 6). Human attention is susceptible to environmental conditions. Undesirable conditions can cause distraction and demand a higher level of focus on the task at hand which is itself related to fatigue (7). Among the inhabitants of large cities, drivers have the highest level of exposure to road traffic noise (8) which affects their cognitive performance (9). Numerous research studies show that 57% of road accidents are caused by driver factors (10) which primarily involve human reaction time and attention (11).

Vibration is another environmental risk factor and is usually accompanied by noise in most occupational environments (12). The most common source of Whole Body Vibration (WBV) are vehicles in which the driver and passengers are exposed to vibration caused by the vehicle and the road itself (13). Vibrations are transferred from the surface of the road into the vehicles, driver and passengers through the foot, seat pan and backrest (14). The results of a review study showed that among 24 studies, 18 had concluded that exposure to vehicular vibration causes fatigue and reduced attention in driving tasks (15). Considering the high number of traffic accidents, it can be said that driver fatigue caused by vibration is an important factor in road safety (16).

There are the numerous studies on the effects of noise exposure on cognitive performance however; fewer studies can be found to assess the effects of combined exposure to road traffic noise and WBV on human subjects. This prompted the authors of this study to evaluate the effects of single and combined exposure to road traffic noise and WBV on various types of attention (Focused, Sustained, Selective, Alternating and Divided in two dimension of auditory and visual) in men so that the differences in the effects of these factors may be revealed.

## Methods

### Study Population

This study was conducted on 24 male subjects, eligible for entry and sampled among students of the Shahid Beheshti University of Medical Science. The subjects were required to fill a demographic information form which included age, sex, height, weight, education, marital status, history of diabetes or cardiovascular disorders and history of sleep disorders. Participants were also required to complete the General Health Questionnaire (GHQ) and the Weinstein Noise Sensitivity (WNS) scale. An audiometry test and an "E" chart optometry test were also conducted to ensure the auditory and visual health of the participants. The inclusion criteria were:

- An age range of 18 to 30 years old.
- No history of underlying disorders such as lung, dermatological, sleep and cardiovascular disorders.
- No history of any other health problem that may affect brain and muscle function.
- Not suffering from temporary illnesses such as cold, nausea or diarrhea.
- No history of upper limb musculoskeletal diseases.
- Not suffering from hearing loss above 25 dBA.
- Not having a visual acuity score lower than 7/10.
- No drug dependencies such as nicotine, alcohol or other drugs.
- No use of sleep inducing pharmaceutical drugs or drugs that weaken the central nervous system during the testing period.
- Exclusion of oversensitive volunteers (as per the WNS scale).
- Scoring 22 or lower on the GHQ questionnaire.

### Testing Room

The test was conducted in an acoustic room (Figure 1), which has a dimension of 4.7 × 4.4 × 2.3 meters (LWH). The brightness and luminance of the acoustic room surface was maintained at optimal levels throughout the testing period using halogen and fluorescent lamps. Mean illuminance for the test desk was determined 160 Lux by using a lux meter (INS -model DX-200; Taiwan).

### Exposure to Noise and Vibration

In order to design the experiments of the present study a matrix was plotted according to Table 1. Twenty-four participants were randomly divided into three groups of eight subjects in each group.

The experiment was conducted randomly in 4 steps during a single day for each subject.

The noise sample contained a bus engine idling, a bus approaching, stopping, idling and departing, a car engine idling and a car passing by, stopping, reversing and driving away (exterior perspective). Samples were downloaded from the websites FindSounds (17) and Soundsnap. To mix, extend the length and modify the noises and obtain steady noise at 55 and 85 dBA levels, the Cool Edit Tool software was used. Finally the noise was replayed using two speakers situated one meter apart on either side of the computer on the test table. Throughout the exposure duration, all the present noises in the acoustic room were measured and monitored using the calibrated sound level meter (B&K-model 2238; Denmark). By constantly monitoring all the noises in the acoustic room, it was possible to adjust the desired noise levels for the current study during the testing period. The noise levels used for this experiment were: 27 dBA representing a background noise of acoustic room, 55 dBA representing the maximum allowable level of outdoor noise for residential area of a country (18) and the threshold level for road traffic noise during day time according to the Environmental Noise Directive 2002/49/EC (3, 19), and 85 dBA representing a noise level higher than the threshold level for road traffic noise and this noise level was chosen based on a study by Nassiri et al. (2016) (20).

A vibration simulation device that uses a vibrating motor to create sine or random wave's vibrations at desired frequencies and intensities on the X, Y and Z axes was used (Figure 1). The Oli Vibrator MVE.440/2M Electric Vibrator Motor (Italy) was connected to a chair using a metal frame. This device can produce vibrations at 1500 RPM with a force of 10 to 200 Kg in three axes. Sine wave vibrations at 3 to 15 Hz and intensities of 0.0, 0.65 and 0.95 $m/s^2$ r.m.s. were set for use in this study. An inverter/transducer (LS- model Ic5; South Korea) was used at 0.37 to 2.2 kW in order to adjust the frequency and acceleration and as shown in Figure 1, it was placed next to the chair. A Bruel and Kjaer WBV measurement device (model 4447; Denmark) according to ISO 2631 (21) and American Conference of Governmental Industrial Hygienists (ACGIH) (22) recommendation was used to ensure the calibration of the vibration rate produced by the simulator. For this study with the purpose of whole-body vibration measurements for a seated person, a rubber seat pad Type 4515-B-002, equipped with an accelerometer Type 4524-B was used. The accelerometer was placed in a Seat Pad that was fixed to the seat using tape. This ensured that the transducer remained at the desired position, withstanding position changes of the test participant and the chair used was an adequately comfortable Renault heavy vehicle seat.

**Figure 1.** Photo of the test room

**Table 1.** Experiments design

| | Step 1 | Step 2 | Step 3 | Step 4 |
|---|---|---|---|---|
| **Group1** | Background noise of acoustic room & Zero Vibration | 85 dBA noise & Zero Vibration | Background noise of acoustic room & 0.95 $m/s^2$ Vibration | 55 dBA noise & 0.65 $m/s^2$ Vibration |
| **Group2** | Background noise of acoustic room & Zero Vibration | 55 dBA noise & Zero Vibration | Background noise of acoustic room & 0.65 $m/s^2$ Vibration | 85 dBA noise & 0.95 $m/s^2$ Vibration |
| **Group3** | Background noise of acoustic room & Zero Vibration | Background noise of acoustic room & 0.65 $m/s^2$ Vibration | 85 dBA noise & 0.65 $m/s^2$ Vibration | 55 dBA noise & 0.95 $m/s^2$ Vibration |

In the study by Barkhordari et al. (2016), the level of WBV exposure on 80 taxi drivers in three different types of vehicles (IK Samand, Peugeot 405, KIA Pride) was measured and the average Acceleration Equivalent Level (Aeq) for the KIA Pride was 0.62 $m/s^2$ r.m.s., which was higher than the other two types of vehicles (23). Khavanin et al. (2012), showed that the maximum average of Aeq for buses was 0.95 $m/s^2$ r.m.s.(24). The vibration accelerations intended for use in this study were chosen based on the results obtained in the aforementioned studies.

**The Attention Test**

The IVA+Plus (Integrated Visual and Auditory) test, is a continuous auditory and visual test that measures a number of factors involved in cognitive performance including attention. In this test, the test taker is required to respond or refrain from responding to 500 stimuli that are only presented for 1.5 seconds each. The participant must click the mouse when they see or hear the number "one" and refrain from clicking when they see or hear the number "two". The main test which is 8 minutes long presents primary and secondary auditory/visual stimuli in combination. Based on the literature review, the rest-time allocated between each exposure condition was set to 15 to 20 minutes (25, 26). Generally, the attention can be an indicator of the number of errors made by the subject, thus higher level of attention will results in lower error number. Additionally, attention also considered reaction time for correct responses (27). In the IVA test, the scores of 5 types of attention was evaluated (28, 29): Focused, Sustained, Selective, Alternating and Divided. The validity of the test showed that the 22 scales of the IVA have a direct and positive relationship with each other (46% - 88%) (30). In the IVA test, the score for each attention type is evaluated based on the following subscales (28) (29):

- Focused attention is evaluated based on prudence and vigilance.
- Sustained attention is evaluated based on consistency, focus and stamina.
- Selective attention is evaluated based on prudence, vigilance and comprehension.
- Alternating attention is evaluated based on consistency, focus, speed, balance and readiness.
- Divided attention is evaluated based on speed and prudence.

The "vigilance" subscale is demonstrative of the test takers ability to distinguish between when to respond to primary stimuli (correct response) and when not to respond to error stimuli (invalid response). An error occurs whenever the test taker incorrectly responds to error stimuli and responds to the primary stimuli carelessly. A low score is indicative of responding with negligence and indifference. The "focus" subscale is demonstrative of the change in reaction times for valid answers. A low score is indicative of weak attention and responding frivolously. The "speed" subscale measures the time taken to respond with a correct answer and assesses brain processing speed. A low score can be indicative of psychomotor retardation or willingness to waste time. The "prudence" subscale is demonstrative of whether the responses are cogitative and reflective or whether they are impulsive and haphazard. A low score is indicative of careless and thoughtless responses or responding without thinking. The "stamina" subscale is demonstrative of whether the reaction times are the same throughout the test or whether the test taker started energetically and then lost his/her energy. This subscale is used to detect problems with long term attention. The "consistency" subscale is demonstrative of the ability to maintain focus on repetitive stimuli for extended periods of time. A low score is indicative of carelessness or absentmindedness when completing repetitive tasks. The "readiness" subscale is demonstrative of whether the test taker is processing information faster or slower than the needed time. This subscale offers a precise evaluation of the test takers lack of attention when he is not performing according to the time constraints. The "balance" subscale is demonstrative of the difference in speed between visual and auditory processing. The "comprehension" subscale is demonstrative of random responses and a lack of comprehension by the test taker (31).

**Metabolism**

The metabolic rate for simple tasks in a sitting position (such as computer-based cognitive tests)

**Table 2.** Some demographic data of the subjects

| | Group | Mean | Std. Deviation | P-value |
|---|---|---|---|---|
| | 1 | 22.87 | 3.10 | |
| Age (year) | 2 | 22.62 | 3.12 | 0.087 |
| | 3 | 22.75 | 2.19 | |
| | 1 | 179.75 | 6.19 | |
| Height (cm) | 2 | 179.00 | 6.54 | 0.771 |
| | 3 | 178.90 | 5.25 | |
| | 1 | 81.87 | 6.80 | |
| Weight (kg) | 2 | 80.12 | 6.48 | 0.528 |
| | 3 | 79.56 | 6.92 | |

was determined to be 1.7 Kcal per minute or 102 Kcal per hour (32), so the given task in the present study placed within the "simple tasks" category.

## Data Analysis

Data analysis was aided by the SPSS v.23 software (Chicago Il, USA). In the descriptive statistics, mean and standard deviation was reported for quantitative variables and frequency and percentage was reported for qualitative variables. A repeated measures regression with a Generalized Estimating Equation (GEE) approach and a first-order autoregressive correlation structure was used to determine the effects of single and combined exposure to noise and WBV on various types of attention. Shapiro-Wilk test was also used to check normal distribution of data.

## Results

The mean and standard deviation for the age of the participants was 22.74 ±2.99 years. The oldest participant was 30 and the youngest was 20 years old. The lowest and highest BMI among the participants were 20 and 29.4 Kg/m$^2$, respectively. The mean and standard deviation for the Body Mass Index (BMI) of the participants was 25.06 ±3.18 Kg/m$^2$. Among the participants, 70.83% were undergraduate bachelor's students and 29.17% were postgraduate master's students.Table 2 represented the some demographic data of the subjects in three groups which indicated no statistically difference among them regarding the demographic data.

Table 3 and 4 indicate the effects of different noise levels and WBV accelerations on the various visual and auditory attention scores. Figures 2 to 4 also show the effects of different noise levels and WBV accelerations on the various visual and auditory attention scores. For the assessment of the single effects of noise on auditory attention scores (Table3, Figure 2), results indicated that with the increase in road traffic noise from 27 to 55 dBA, the mean score of all attention types decreased and this reduction was significant for Focused (P=0.0001), Selective (P=0.004), Alternating (P=0.001) and divided attention (P=0.023). Also, with the increase in noise levels from 27 to 85 dBA, the mean scores of all attention types significantly decreased (Focused

**Table 3.** Auditory attention scores in different exposure condition to noise and WBV compared to background

| | Vibration acceleration (m/s$^2$) | 0 | | | 0.65 | | | 0.95 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Noise level (dBA) | 27 | 55 | 85 | 27 | 55 | 85 | 27 | 55 | 85 |
| Focused Attention | Beta | 0 | -24.52 | -30.08 | -6.77 | -43.83 | -15.15 | -13.90 | -3.52 | -41.71 |
| | p-value | - | * 0.0001 | * 0.0001 | 0.198 | * 0.0002 | * 0.029 | * 0.038 | 0.634 | * 0.0001 |
| Sustained Attention | Beta | 0 | -9.25 | -10.43 | 3.46 | 2.31 | 9.7 | 2 | 14.81 | 1.43 |
| | p-value | - | 0.063 | * 0.055 | 0.499 | 0.708 | * 0.055 | 0.651 | * 0.003 | 0.394 |
| Selective Attention | Beta | 0 | -26.40 | -34.80 | -4.84 | -46.72 | -15.72 | -12.92 | -9.72 | -40.84 |
| | p-value | - | * 0.004 | * 0.0002 | 0.327 | * 0.0002 | * 0.005 | * 0.015 | 0.222 | * 0.0001 |
| Alterntng Attention | Beta | 0 | -12.7 | -8.12 | -3.12 | -8.25 | -0.25 | -6.56 | -2.25 | -14.37 |
| | p-value | - | * 0.001 | * 0.046 | 0.378 | * 0.038 | 0.942 | * 0.034 | 0.596 | * 0.0001 |
| Divided Attention | Beta | 0 | -8.83 | -8.95 | 1.29 | -6.71 | -4.21 | 1.41 | -4.83 | -17.77 |
| | p-value | - | * 0.023 | * 0.004 | 0.548 | * 0.003 | 0.230 | 0.527 | 0.125 | * 0.0001 |

*. Statically significant

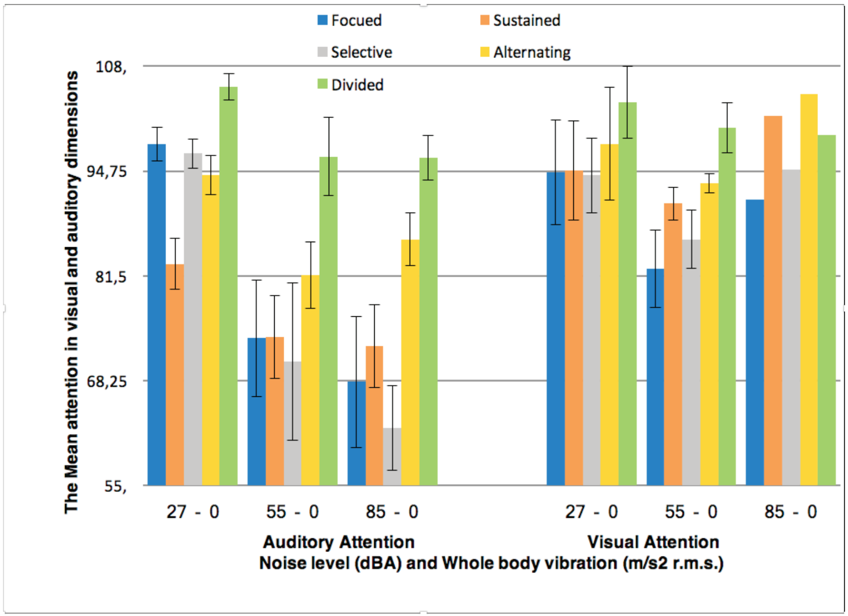


**Figure 2.** Auditory and Visual attention scores in single exposure to noise compared to background

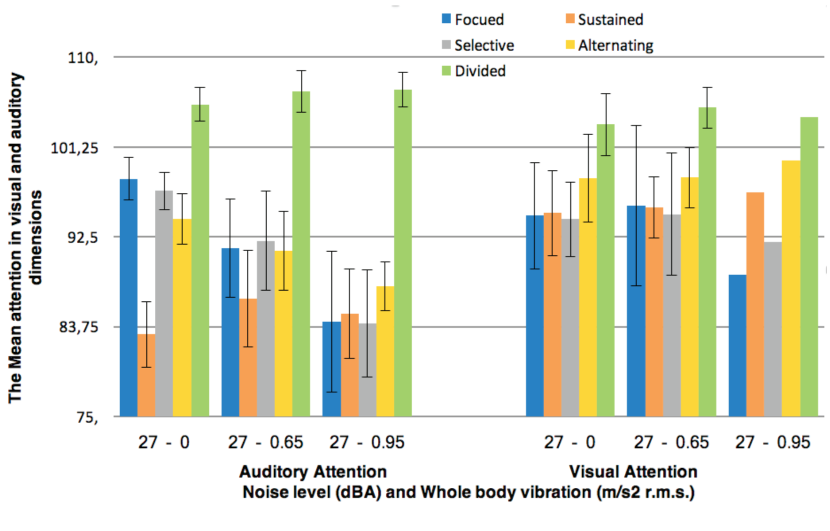


**Figure 3.** Auditory and Visual attention scores in single exposure to whole body vibration compared to background

P<0.001, Sustained P=0.055, Selective P<0.001, Alternating P=0.046 and divided P=0.004 respectively). For the assessment of the single effects of WBV on auditory attention scores (Table 3, Figure 3), results indicated that with the increase in vibration from zero to 0.65 $m/s^2$ r.m.s., there was no significant difference in the mean score of all attention types (Focused P=0.198, Sustained P=0.499, Selective P=0.327, Alternating P=0.378 and divided P=0.548 respectively). With the increase in vibration from zero to 0.95 $m/s^2$ r.m.s., the scores for Focused P=0.038, Selective P=0.01 and Alternating P=0.034 attention decreased significantly. Regarding the effects of combined exposure to road traffic noise and WBV on auditory attention (Table 4, Figure 4), the results showed that in vibrations 0.65 $m/s^2$ r.m.s., increasing noise levels from background to 55 dBA caused a significantly drop in the scores of all attention types (Focused P<0.001, Selective P<0.001, Alternating P=0.038 and divided P=0.003

respectively). Vibration 0.65 $m/s^2$ r.m.s. and increasing noise level from background to 85 dBA, lead to significantly decrease in scores of Focused (P=0.029) and Selective (P=0.005) attention. Also in vibration 0.95 $m/s^2$ r.m.s., increasing noise levels from background to 55 and 85 dBA caused a fall in the scores of all attention types (except Sustained attention) and this drop was significant for Focused, Selective, Alternating and divided attentions (P<0.001, for all), in 85 dBA noise.

In zero vibration, intended for the assessment of the single effect of noise on visual attention scores (Table 4, Figure 2), results indicated that with the increase in road traffic noise level from 27 to 55 dBA, there was no significant difference in the mean score of all attention types (Focused P=0.094, Sustained P=0.405, Selective P=0.116, Alternating P=0.388 and divided P=0.361 respectively). Also, with the increase in noise levels from 27 to 85 dBA, the mean scores for Sustained (P=0.024) and Alternating (P=0.003) attention statistically rose. In 27 dBA noise, intended for the assessment of the single effect of vibration on visual attention scores (Table 4, Figure 3), results indicated that with the increase in vibration accelerations from 0 to 0.65 $m/s^2$ r.m.s., there was no significant difference in the mean score of all attention types (Focused P=0.845, Sustained P=0.878, Selective P=0.881, Alternating P=0.987 and divided P=0.480 respectively). Also, with the increase in vibration magnitude from 0 to 0.95 $m/s^2$ r.m.s., there was no significant difference in the mean score of all attention types (Focused P=0.387, Sustained P=0.582, Selective P=0.647, Alternating P=0.604 and divided P=0.779 respectively). Regarding the effects of combined exposure to road traffic noise and WBV on visual attention (Table 4, Figure 4), the results showed that when exposed to vibrations at 0.65 $m/s^2$ r.m.s., with increasing noise levels from background level to 55 dBA, there was no significant difference in the mean score of all attention types (Focused P=0.796, Sustained P=0.226, Selective P=0.647, Alternating P=0.361 and divided P=0.295 respectively). Vibration 0.65 $m/s^2$ r.m.s. and increasing noise level from background to 85 dBA, lead to significantly increase in scores of Focused (P=0.013), Sustained (P<0.001) and Selective (P=0.001) attention. When exposed to vibrations at 0.95 $m/s^2$ r.m.s. however, increasing noise levels from background level to 55 dBA caused a significantly rise in the scores of Focused (P<0.001) and divided (P=0.008) attention. At 0.95 $m/s^2$ r.m.s. vibration, the increase in noise levels from background level to 85 dBA caused a significantly decrease in Divided attention (P=0.014).

## Discussion

In the present study, increases in noise levels caused a significantly reduction in auditory attention when going from 27 to 55 and 85 dBA. The results of a study by Zeydabadi et al. (2019) indicated that exposure to noise higher than 85 dBA affected

**Table 4.** Visual attention scores in different exposure condition to noise and WBV compared to background

| | Vibration acceleration ($m/s^2$) | 0 | | | 0.65 | | | 0.95 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Noise level (dBA) | 27 | 55 | 85 | 27 | 55 | 85 | 27 | 55 | 85 |
| Focused | Beta | 0 | -12.17 | -3.42 | 0.99 | 1.02 | 8.96 | -5.73 | 13.83 | -10.16 |
| Attention | p-value | - | 0.094 | 0.528 | 0.845 | 0.796 | * 0.013 | 0.387 | * 0.0001 | 0.149 |
| Sustained | Beta | 0 | -4.20 | 6.90 | 0.57 | 4.53 | 9.06 | 2.02 | 4.94 | -1.01 |
| Attention | p-value | - | 0.405 | * 0.024 | 0.878 | 0.226 | * 0.0001 | 0.582 | 0.302 | 0.777 |
| Selective | Beta | 0 | -8.12 | 0.67 | 0.49 | 1.41 | 8.96 | -2.21 | 5.87 | -5.29 |
| Attention | p-value | - | 0.116 | 0.846 | 0.881 | 0.647 | * 0.001 | 0.647 | 0.125 | 0.286 |
| Alternting | Beta | 0 | -4.97 | 6.28 | 0.09 | 2.49 | 3.2 | 1.71 | 0.07 | -1.1 |
| Attention | p-value | - | 0.388 | * 0.003 | 0.987 | 0.361 | 0.402 | 0.604 | 0.978 | 0.437 |
| Divided | Beta | 0 | -3.2 | -4.20 | 1.65 | 0.81 | 0.94 | 0.69 | 5.62 | -9.44 |
| Attention | p-value | - | 0.361 | 0.185 | 0.480 | 0.295 | 0.773 | 0.779 | * 0.008 | * 0.014 |

*. Statically is significant

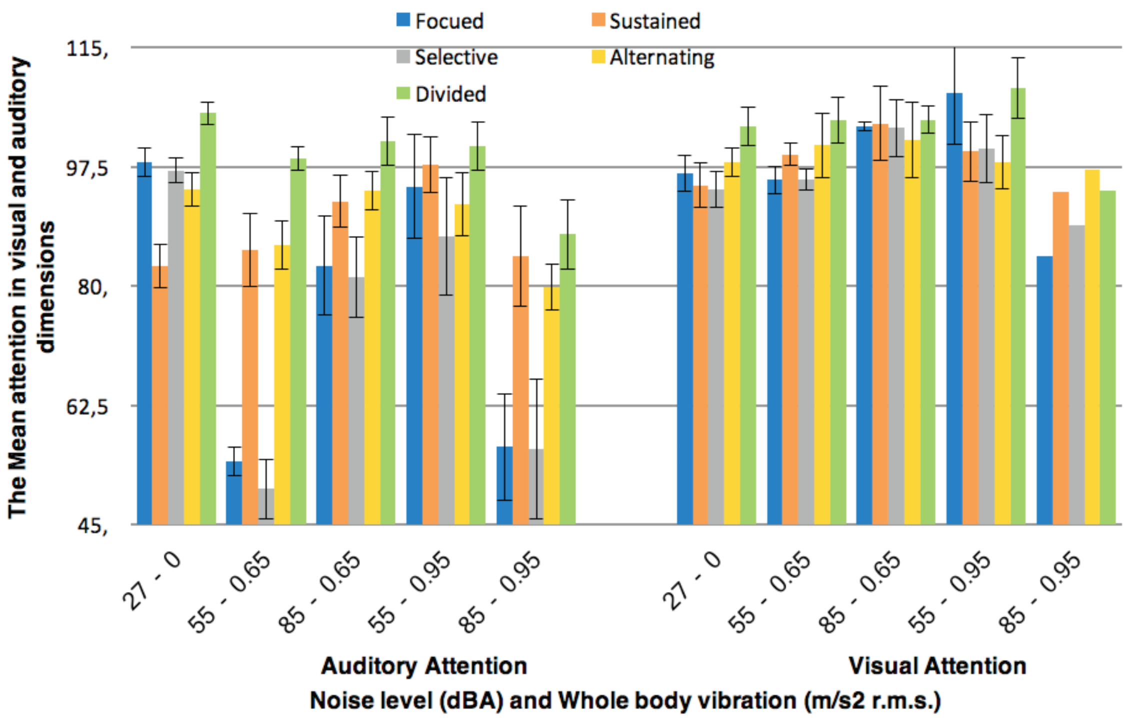


**Figure 4.** Auditory and Visual attention scores in combined exposure to noise and whole body vibration compared to background

certain aspects of cognitive performance (reaction time, attention and memory) (33). A study by Jafari et al. (2019) showed that noise levels seem not to have the appropriate sensitivity at levels below 85 dBA on cognitive performance (34). The results of these studies are in agreement with the present study.

It has long been known that cognitive processing is easily disrupted by adverse environmental stimuli such as noise that divert attention away from the person's main task. This effect may be due to the competition for attention resources by target stimuli and disruptive stimuli (35). There are some studies with contradicting results where noise exposure actually caused short term improvement in cognitive performance (36). Also, according to Poulton's arousal theory (37), at the onset of exposure to noise, the temporary increase in arousal has been occurred because of reducing the effects of exposure, so in the short term, people's attention levels will rise and by the passage of time the effect of arousal will decrease and the effects of noise will appear (38). The results of the present study regarding the rise in some scores of visual attention due to the increase in noise levels from 27 to 85 dBA were in agreement with these studies and this theory. However, this was not the case in auditory attention, as increasing noise level to 85 dBA caused auditory attention to significantly decrease. This may be due to the fact that in the auditory test, the participant had to hear and distinguish both the traffic noise and the noise related to the IVA+Plus test (the number "one") which pronounced the adverse effects of noise on their attention. In similar studies however, it has been stated that the adverse effects of noise exposure on cognitive performance occur at high noise levels (85 dBA or higher) which, considering the noise levels chosen in the present study and the short term exposure, the resulting effects of noise exposure on cognitive performance were somewhat contradictory. Naserpour et al. (2014) concluded that raising noise levels caused an increase in the levels of Sustained attention and attention percentage. They also stated that in such studies, participants were highly motivated to overcome the disruptive environmental conditions and wanted to obtain the best results from their performance (39). This was enough of an effort to mask the adverse effects of noise in simple cognitive tasks. The results of Naserpour et al. were in agreement with the present study.

Regarding of the effects of exposure to vibration, in a study by Khosrowabadi et al. (2018), the results showed that increasing WBV acceleration caused a significant reduction in visual and auditory attention (40). The results of the present study showed that there was not a significant difference in visual attention scores but a significant fall in some scores of auditory attention due to the increase in vibration acceleration from zero to 0.95 $m/s^2$ r.m.s. which were partly in agreement with previous study. As is apparent, based on the design of the study and the vibration accelerations used, the resulting effects of WBV on performance parameters varies to some extent. The reason why effects of vibration on visual and auditory attention were not significant in the present study may be due to the shortness of the experiment duration or the inability of the test to determine small changes.

Regarding of the effects of combined exposure to noise and vibration, Mohammadian et al. (2015) assessed the effects of simultaneous exposure to WBV and noise on cognitive performance. Their results showed that at a low mental processing state, the interactions of noise and vibration caused a reduction in mental performance (41). Even though the noise levels and vibration accelerations used in the present study were lower than the values used in Mohamadian et al., the results pertaining to auditory attention scores are in agreement with each other.

## Conclusions

In this study we found that single and combined exposure to environmental stressors under investigation had a predominantly negative effect on auditory attention while the effects of single exposure on visual attention were inconclusive. Also, it appears that combined exposure to medium vibration acceleration and high noise level can impede visual cognitive performance, but other combined exposure conditions can improve it. Definitive conclusions however require further systematic and comprehensive experiments. The limitations of this study include the following: reducing the exposure time due to ethical issues, performing the experiments in laboratory conditions (acoustic room), due to the presence of many interfering factors in the real environment. The suggestion for future studies is to obtain heart rate and blood pressure to discuss more-in-depth the physiological effects of exposure to noise and WBV on visual/auditory attention.

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