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Research paper

A Comparison of Random and Sinusoidal Vibration Effect on Human Alertness Level

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Abstract

It is difficult to identify the means or models developed specifically to enlighten the society on what vibration can do to a normal human body – one of the more popular vibrations' effects is fatigue. As a form of impairment towards completing physical tasks, effects of fatigue have been studied extensively in various research settings and perspectives; especially concerning vehicle drivers. However, the distinct lack of prior studies on vibrations' effects on seated drivers' mental alertness has initiated our team to study further; having many confounding factors does make it complicated. Consequently, we began by ensuring the actual link between while-body vibration (WBV) and human drowsiness. For that, a custom-made setup was constructed specifically for testing human vibration. Low-frequency sweep sinusoidal and random whole-body radiation were used methodically on 10 volunteers. We set 0.3 ms^{-2} r.m.s. for 20 minutes because the values reflect perceived vibration which were experienced by the drivers. Electroencephalographic (EEG) signals would indicate if there is any kind of changes in drowsiness levels whereas the analysis was completed with two brainwave spectrums (theta waves and beta waves. The results proved that there is a link between WBV and drowsiness.

Keywords: *drowsiness; wakefulness; electroencephalogram; WBV;*

1. Introduction

Statistics have shown how drowsiness among drivers is now a main reason for accidents on the roads [1], for instance around 25% of road accidents were showing signs of drivers did not have enough rest. Ironically, it is higher compared to the numbers on drunk driving [2]. While drivers' lack of rest affected drivers' concentrations significantly, researchers have not focused on drowsiness caused by WBV in their respective vehicles. More in-depth, correlational studies are needed to investigate more on the dynamic link(s) among vehicle drivers, vibrations produced by their transportations, and drowsiness. Just like any other medical condition, drowsiness is as complicated and require more of both quantitative- and qualitative-based studies. There were studies which have managed to link WBV with prognosis such as back pain, heart-rate variability [3]–[6], vision disturbance and balance [6]–[8], and disrupt the use of neurological conditions and muscle by having the role – a stressor.
For a seat in a typical car, its structure is known to be exposed to certain vibrations generated by powertrain and various types of roads. A car's vibration modes normally occur below 60Hz, be it resonant frequency or correspondence mode shapes [11]. This is generally different compared to 15Hz-resonance of a human body [7], where it has been a critical factor for car manufacturers to study their potential customers' perception towards the auto industry and the comfort level that they are seeking whenever they want to drive a car [12]–[13].
As a result, the ISO 2631-1 (1997) International Standard was established to assess WBV and its effects [14]. Since then, there is still a significant lack of resources or statistical data concerning the link between WBV and drivers' drowsiness. Defined as "*a transitory period between awake and sleep*" [15], drowsiness can be detected when a driver's brainwave activity is measured with electroencephalography (EEG) signals [16]. It is a proven method to distinguish drowsiness [17]–[18] because of how EEG calculate the disparities among brainwave activity in microvolt range.
The classification of brainwave activities depends on their rhythm and frequency range as listed below [4]:

i. *Delta* (< 4 Hz)
   - Associated with deep sleep [19]
ii. *Theta* (4 – 7.5 Hz)
   - Associated with drowsiness [16]
iii. *Alpha* (8 – 13.5 Hz)
   - Associated with more comfortable situations [19]
iv. *Beta* (14 – 30.5 Hz)
   - Associated with normal rhythm; attentive [16]

At this stage, the researchers have begun setting up experiment procedures to determine whether to what extent the WBV affects the drowsiness levels of seated drivers. The targeted output is in the form of quantitative data, discussions and recommendations for the betterment of drivers' skills.

2. Methods

2.1. Recruiting students as sample for study

10 voluntary, male university students were recruited with these basic parameters:
- Healthy; hearing, vision, back body, neck
- Mean (**M**) for age: 23 years

- **M**, height: 168.2 cm
- **M**, weight: 64.2 kg
- Free from recent medicinal drug use or caffeine
- Had enough sleep a day prior the experiment

2.2. Ethics in Research

A written agreement was handed to all voluntary recruits, detailed with written information and verbal briefing prior to the experiment. Necessary information such as their rights to proceed / resign from experiment, confidentiality of research data or outputs, informed consents and further introduction to laboratory equipment have been duly explained in length. Vibration level was set and maintained at safe levels which are following Iso 2631-1 (1997) International Standards [14].

2.3. Research equipment

A custom motion-base vibration simulator had been constructed specifically for this study; which included an industry-standard car seat. The seat was mounted on a vibration table set up on top four inflatable air cushions; which ensures dynamic rigidity while maintaining the frequency to stay below 200 Hz. The purpose is to avoid any unwanted contact between the natural frequency of the table and the seat's structural dynamics. A servo-controlled hydraulic actuator had been put at one side of the table to provide excitation input needed – this ensures varying positions for the excitation input capturing process from the vibration modes and resonant frequencies

2.4. Overall Procedures during Experiment

Time	9 am – 12 pm / day
Room Conditions	Comfortable (noise, temperature, illumination)
Vibration Conditions (20-30 minutes) (seating / non-seating)	i. No vibration ii. Random vibration iii. Sinusoidal vibration
Informed consent	Signed with verbal confirmation prior to beginning the experiment

All participants were told to assume their comfortable seating / non-seating positions according to their individual preferences – as long as their hands were put on their lap, their back was put on the backrest, and the footrest would be used to put their feet in order to avoid being interrupted with possible vibrations from the floor surface. Another task for them was to concentrate on the cross sign on the wall which had been put up at the same height with their eyes. This is to assist them in limiting their body movement. For the vibration inputs, gaussian random and Sweep Sine were utilized within 1 – 15 Hz frequency range. As mentioned earlier, vibration acceleration level was maintained at 0.3 r.m.s. during the entire procedures with EEG headset placed gently on their scalp. Acceptable level of contact of their scalp and electrodes were indicated with green light and further reinforced with saline solution.

2.5. Eeg recording

Headset model	Emotive EPOC 14-channel wireless Neuro-headset (Emotive Systems, Inc., made in California)
Placing the electrodes	International 10-20 System
EEG signals	Recorded at 128 Hz
Time of recording: *Before vibration* *During vibration* *After vibration*	 2 minutes 20 minutes 2 minutes
Saline solution usage	Yes
Impedance of contact	Maintained at < 5 KΩ

2.6. Eeg analysis

Software	EEGLAB software (version 9.B, offline)
Raw data filter	$0.5 < x < 30$ Hz
EEC data	Segments of 10-second epoch
Possible EEG data contaminated	Blinking the eye(s), muscle activity, pulse
Solution for contaminated data	Independent Component Analysis (ICA)
Collected data	Artifacts-free data; analyzed through theta and beta frequencies
Frequency domain analysis	Fast Fourier Transform (FFT) algorithm; calculating: - absolute (μV²/Hz) - power density - relative (%) power density - mean frequency (Hz) within each of the sub-bands
Quantitative data analysis	SPSS (version 20.0); significant value set at $p < 0.05$

Normalization of data distribution was confirmed through log transforming the absolute power

3. Results

3.1. Beta Activity

Figure 1 indicates the F3 and F4 scalp positions were selected for the calculations of relative wavelet energy / event-related spectral power for Beta rhythm (14 – 30.5 Hz). Having associated with alertness, a drop in Beta rhythm would show diminishing state of being fully awake.

Highlighted numbers above bars refer to the **M** of every condition after 20 minutes. 100 has been set as the boundary level for drowsiness baseline, hence any value recorded below 100 would distinguish a drop in being alert.

For random (RVC) and sinusoidal (SVC) conditions, their input vibration levels have been adjusted to be the same; no adjustment has been made for NVC.

The exposure results of RVC and SVC indicate a significant drop ($p < 0.05$) in beta activity, hence it can be said that the correlation is the effect of exposure to sinusoidal vibration is bigger compared to RVC's exposure. This can be further described with the observation of harmonic features of sinusoidal vibration.

The rise of beta activity in NVC, on the other hand, proved that the participants involved were fully awake after sitting comfortably for 20 minutes straight without any hint of vibration input. Hence, it can be said that the correlation is the drop in the beta activity with vibration in sinusoidal condition. This is because a bigger drop in beta activity was observed in sinusoidal vibration.

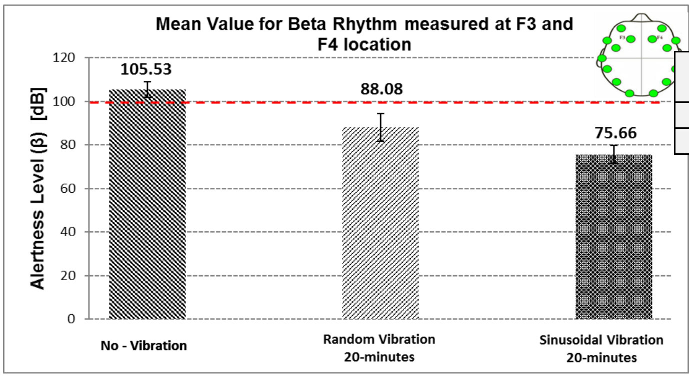

Fig. 1: **M**, of Beta Rhythm Brainwave Power Spectrum for "*NVC*", "*RVC*", and "*SVC*" measured at F3 and F4 scalp locations. A significant drop in the beta activity can be observed in vibration conditions – this may correlate to the drop in the wakefulness state

3.2. Theta Activity

Figure 2 indicates the F3 and F4 scalp positions were selected for the calculations of relative wavelet energy / event-related spectral power for Theta rhythm (4 – 7.5 Hz).
Highlighted numbers above bars refer to the **M** of every condition after 20 minutes. 100 has been set as the boundary level for drowsiness baseline, hence any rise in Theta activity recorded would distinguish in nearing towards being drowsy.
For RVC and NVC, their input vibration levels have been adjusted to be the same; no adjustment has been made for NVC.
The exposure results of RVC and SVC indicate a significant rise ($p < 0.05$) in theta activity, hence it can be said that the correlation is the effect of exposures to sinusoidal vibration and random vibration are bigger compared to NVC's exposure. This can be further described with the observation of in NVC, the **M** is adjacent to 100.
This shows that the significant rise of theta activity in both random vibration and SVCs has proven that there is no significant difference when it comes to the wakefulness state pre- and post-20 minutes of sitting comfortably. The **M** of theta activity in sinusoidal vibration was bigger than **M** of theta activity in random vibration, hence also proving that sinusoidal vibration naturally affects drowsiness more than random vibration.
Overall, the concluding statement is a drop the state of being alert can be explained by observing the combination of beta and theta activities; and the sinusoidal vibrations influences more than the other two.

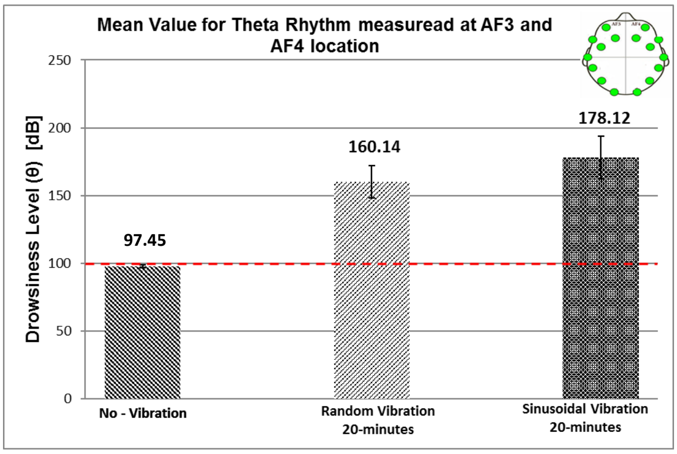

Fig. 2: **M**, of Theta Rhythm Brainwave Power Spectrum for "*NVC*," "*RVC*," and "*SVC*" measured at F3 and F4 scalp locations. A significant rise in the Theta activity can be observed in vibrations conditions – this may correlate to the drop in the wakefulness state

Table 1: Quantitative data analyzed. *p*-value was ≤ 0.05, indicating that vibration does cause drowsiness. Furthermore, *p*-value was 0.05 for theta activity and 0.20 for beta activity in NVC.

After 20 minutes	NVC	RVC	SVC
Beta (β)	0.20	0.01	0.00
Theta (θ)	0.05	0.00	0.01

Significance level = $p < 0.05$

4. Discussion

It is reiterated that further or more advanced studies on the correlations between vibrations and drowsiness must be promoted to significantly reduce the number of road accidents caused by drivers' increasing drowsiness levels. It can be acknowledged that as of now, these data can be contributed to the body of knowledge concerning the relationship WBV and drivers' drowsiness – which refers to body vibrations as cause. With the detailed comparisons between NVC, RVC, and SVC, more hypotheses, parameters, and variables can be measured in in future studies. At present, our data concluded that body vibration, even at low frequency range (which has been declared safe according to the International Standards), may still cause drowsiness among drivers in a comfortable seated position. In addition, SVC affects the drowsiness levels more compared to NVC and RVC. This is in line with the principle of vibration exposure can trigger many sensory receptors which would transform the feelings into electrical impulses by Landstrom et al. [20]. These impulses will then be processed by the brain and the stimuli necessary as reaction. These processes will be further influenced by vibrations transmitted onto the drivers' bodies and alter their wakefulness states.
As body receptors, brain's stimuli and responses, and electrical impulses are already complicated to be measured, the vibrations would be an alternate medium to discover more about human sensation and feelings whenever drivers would feel anything peculiar while driving. With the addition of the fact that every individual would naturally has differing levels of physical / mental tolerance and resilience, it is highly recommended for other researchers to focus on measuring brain wave activity to study drowsiness and human vibrations – just like how we have proven the effectiveness with our EEG experimental methodology.

5. Conclusion

In short, further adjustments, reviews, or improvements in the ISO 2631-1 (1997) International Standards [14] are highly recommended to be done in future meetings and discussions. As the elements of drowsiness have yet to be explored to the fullest, future studies relating vibrations to it would be significantly beneficial to the body of knowledge and to the human population in general.

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