Visual Acuity under Low Frequency Vibrations

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Abstract

VISUAL acuity under low frequency vibrations in the range of 6 to 12 Hz at an amplitude of 0.5 g has been studied for different durations of vibrations. An electrohydraulic vibration simulator was used for these studies. Maximum impairment of visual acuity was observed at 6 Hz and 12 Hz.

Studies were also carried out on the comparative decrement in visual acuity with subject and object vibrating as against object stationary and subject vibrating. The former showed a marked decrement compared to the later.

Another comparative study on horizontal and vertical display showed a high degree of deterioration in visual acuity with vertical display for Gz vibrations.

Introduction

Man experiences oscillatory disturbances in the act of walking, running, dancing, riding horseback or riding in spring or unspring carts, wagons and coaches. We have experienced the sickening oscillations of sea transport and the lurches and swaying of street carts and trains throughout their development. The severe whole body vibrations in aircraft and space vehicles are known to affect crew performance and contribute to accidents.

In aviation a number of causative factors operate in producing vibrations:

(a) High speed flying at low altitudes through turbulence, when an air aircraft is struck at random by gusts of moving air.

(b) In rotary wing aircraft (Helicopters) the frequency of vibration is related to the speed of the rotor. Other sources of vibrations are engine, transmission system and tail rotor.

(c) Supersonic passenger aircraft with speed 2 mach or more at high altitudes. At altitudes severe turbulence is rare but moderate disturbance of aircraft causes longed effect because of low overall damping provided by the rarefied air.

(d) When powerful weapons such as guns cannons are fired from the aircraft, impacts transmitted through gun mountings to the airframe. Frequency of vibration depends upon the rate of firing and the response of the structure to each impact.

Visual acuity under vibrations

Vibrations of the viewer or the object viewed blurs the vision and this is usually presumed to be due to movement of the retinal image at a speed too great to be followed by the eye movements. Large numbers of tests have been employed to test visual acuity under vibration. These include the Landolt 'C' by Dennis Elwood,[2] Drazin,[3] Schmitz and Simons.[10] The use of printed letters or numbers was employed by Dennis,[1] Guignard,[5] Mozell and White, Drazin.[4] Jones and Drazin[6] have investigated the legibility of test material vibrated with respect to a stationary viewer.

Studies carried out by Dennis and Elwood, Dennis,[1] Lange and Coermann,[7] Mozell and White reveal that the visual acuity is reduced by vertical whole body vibrations at acceleration amplitude between 0.1 and 0.75 g in the frequency range of 4 to 40 Hz. Masumitsu Oshima[8] on investigation of the action of vibration on visual acuity has shown that the decrement of visual acuity becomes greater with increasing frequency and increasing amplitude. The greater the frequency the greater the difference

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decrement of visual acuity between each amplitude. It was also shown that the decrement of visual acuity is not linearly related to the amplitude. Is considered to be controlled by the force of ...tion of the eyeball.

In general no clear cut evidence of decrement visual acuity which is purely frequency dependent amplitude dependent has emerged. The evidence conflicting because different workers have used different methods for measuring visual acuity under vibrations.

The purpose of present study is to investigate the effect of whole body vibrations on visual acuity the frequency range of 6 to 12 Hz. The amplitude employed in all the four frequencies is 0.5 G. The duration of vibration exposures for each subject is ... minutes.

Material and Method

The vibration simulator facility at the Institute of Aviation Medicine, IAF has been used for this study. This simulator is an electrohydraulic type which is fabricated to simulate sinusoidal vibrations in the axis from 0 to 20 Hz with variable amplitude. The aim is to simulate gust induced vibrations as one comes across during low altitude high speed flying.

The vibration simulator essentially has a 'mild steel' vibrating platform of 5′ diameter which is mounted by a cylinder and a piston. A 10 HP induction type motor operates the 8.3 HP Vickers pump which forces the spindle oil with a pressure of ... PSI to the piston assembly through a four way valve. The amplitude of vibration depends on the pressure at which the spindle oil is pumped to the piston assembly. The pressure of the spindle oil is regulated by adjusting the worm screw attached to the Vickers pump. A 1 HP varidrive motor having an RPM of 380-3565, makes it possible to achieve the required frequency range by operating a spindle mechanism on a graduated scale. The vibration simulator is shown in Photo 1. It has the following accessories:

(a) A chair firmly mounted on the vibrating platform.
(b) Slotted angle frame in front of chair for mounting various charts and instruments for visual acuity studies.
(c) An accelerometer having a linear response mounted to the base of the chair for monitoring the amplitude and frequency of vibrations.

Photo 1.
Vibration simulator with a subject

(d) Source of light for controlled illumination.
(e) Encardio-rite (Model 535) having two channel amplifier for recording the frequency and the amplitude of vibration.

Calibration for vibration simulator, for various frequencies has been done using a vibrograph. The calibration for amplitude of vibration is done with the help of the accelerometer which is fixed to the base of the chair.

Instrumentation for visual Acuity studies

The test employed for visual acuity during this study was Snellen's near vision test type of charts which were fixed in a small frame which was in turn mounted on the frame fixed to the vibrating platform. These were displayed in front of the subject at a distance of 28″ (71 cms). The illuminance level was kept constant at 50 Lux. In another set of experiments Landolt's rings were displayed at a distance of 2.75 metres mounted on a frame outside the vibrating platform. Two sizes of Landolt's rings with opening of 1.2 mm and 1.8 mm were used. Both these sizes were displayed with the gaps parallel and perpendicular to the direction of vibration. The illumination was kept at 7 Lux.

Ten male volunteers with normal visual acuity were chosen for the present study. The subject, after being seated and harnessed was asked to read the various test charts displayed. Time taken to read a particular chart size during resting conditions was noted.

The subject was then vibrated at 6, 8, 10 & 12 Hz at 0.5 G amplitude and time taken to read Snellen's chart at 0, 10, 20 and 30 minutes interval for each frequency, was recorded. Similar readings were taken with Snellen's chart kept stationary, fixed at the same distance, but on a frame mounted outside the vibrating platform.

During studies with Landolt's rings the time taken to identify the direction of opening both for the small and large sized rings were recorded separately for parallel and perpendicular displays; both with and without vibration. Only two frequencies 6 and 8 Hz at 0.5 G amplitude, were used for this set of studies. The readings were taken at 0, 10, 20 and 30 minutes interval.

Results

Visual acuity measurements for vibration frequencies of 6, 8, 10 and 12 Hz at 0.5 G amplitude for different subjects were analysed. It is observed that in the interpretation of visual acuity decrement under vibration it is advantageous to express visual acuity in terms of time taken per word in reading letters of different sizes. Conventional approach of assessing visual acuity by determining the number of errors is not adopted to as there is a tendency for the errors to decrease if the subject is given more time. Time taken per word is calculated by dividing the total time taken to read a particular chart size by the total number of words contained in the chart. It is also seen that the time taken to read Snellen letters is longer and reaches a minimum value with increasing size of the letter. Once this minimum is reached there is no further decrement in time per word. The angle substended at the eye (visual angle), by letters of different sizes was calculated by measuring the height of the letter in a particular chart size divided by the distance between the chart and the eyes. The visual angle thus calculated is expressed in minutes. The resolution of the letters is proportional to this angle.

Comparison is made between angular sizes which are read within the same time under different vibration conditions. Table I shows decrement in visual acuity for vibration frequencies of 6, 8, 10 and 12 Hz for different subjects and for different times under vibration (*ie*: 0, 10, 20 and 30 minutes).

Table II shows mean decrement in visual acuity in angles for frequencies of 6, 8, 10 and 12 Hz for different durations under vibration.

Tables III and IV show decrement in visual acuity with subject and object vibrating (object outside the vibration platform) as compared to object stationary and subject vibrating.

Decrement in visual acuity with "Gaps" of Landolt's rings parallel (Horizontal) and perpendicular (Vertical) to the direction of vibration were also calculated. Low illumination levels were used because it was difficult to reduce the size of Landolt's rings any further than done in this study. With the present experimental arrangement it was not feasible to project the normal sized rings at a distance of 6 metres. The frequencies used for Landolt's rings study were 6 and 8 Hz (at 0.5 G amplitude).

Tables V and VI show comparative decrement in visual acuity between vertical and horizontal display at 6 Hz while Tables VII and VIII show comparative decrement at 8 Hz.

Discussion

From Table II it is seen that maximum decrement in visual acuity is in the frequency range of 6 Hz immediately after the start of vibration and 10 minutes after the start of vibrations in the frequency range of 12 Hz. It is also seen that as the duration of vibrations increases, the decrement in visual acuity is less and this reduction stabilises within 10 minutes after start of vibration after which there is hardly any further decrement in visual acuity. This trend is observed in all the frequencies used for the present study (*ie*: 6, 8, 10 and 12 Hz at 0.5 G amplitude). This shows a certain degree of adaptation (to the vibration conditions) of the functions involved in visual acuity. It is therefore obvious from this study that when intermittent or random vibrations are experienced by an operator he does not get time to adapt to vibration conditions and the decrement in visual acuity will remain at the peak level. This situation is often experienced during low altitude high speed flying when pilot is likely to be subjected to gust induced vibrations at random.

TABLE I

Decrement in visual acuity in angles (in minutes) for various frequencies under different vibration conditions.

Time under vibration	Immediate				10 minutes				20 minutes				30 minutes			
	Decrement in visual acuity in angles in mts				Decrement in visual acuity in angles in mts				Decrement in visual acuity in angles in mts				Decrement in visual acuity in angles in mts			
Frequency in Hz	6	8	10	12	6	8	10	12	6	8	10	12	6	8	10	12
SUBJECT																
I	5.5	4.3	2.0	5.5	8.2	4.6	1.3	7.2	7.1	4.2	2.5	3.7	4.3	4.1	2.7	4.7
II	5.1	2.5	5.6	4.8	4.7	2.5	2.9	4.8	4.2	2.4	6.9	5.2	4.0	2.7	5.1	5.0
III	6.4	4.1	3.7	3.3	5.3	3.9	4.4	4.8	4.4	3.4	2.7	4.9	4.6	4.3	3.6	4.9
IV	8.2	6.0	4.6	4.9	10.3	5.7	9.9	9.9	10.4	4.8	4.6	10.3	10.3	4.4	4.4	10.0
V	9.2	5.2	9.3	7.4	6.1	5.4	—	3.1	5.4	5.4	8.3	4.8	—	5.4	9.9	10.0
VI	8.2	4.8	—	5.4	9.9	4.3	—	6.2	4.9	2.8	4.4	4.7	—	4.1	3.9	4.8
VII	10.2	6.4	—	—	7.6	6.2	—	8.3	7.6	6.6	—	4.4	7.6	5.6	—	4.5
VIII	4.5	3.0	—	—	4.3	4.0	—	10.3	4.1	2.9	—	—	4.0	3.4	—	4.6
IX	—	3.6	—	—	5.0	4.2	—	5.2	4.2	4.4	—	—	4.4	3.6	—	—
X	4.5	2.2	—	—	4.4	4.2	—	—	3.8	5.8	—	—	3.7	2.1	—	—

TABLE II

Mean decrement in visual acuity in angles (in minutes) for different frequencies

Time under Vibration	Mean decrement in visual acuity in angles in mts. frequencies 6Hz	8Hz	10Hz	12Hz
Immediate	6.9	4.3	5.0	5.2
10 mts	6.6	5.0	4.6	6.6
20 ,,	5.6	4.2	4.9	5.4
30 ,,	5.4	4.0	4.9	5.6

TABLE III

Decrement in visual acuity with both subject and object vibrating in comparison to a stationary object with subject vibrating only

Amplitude of vibration 0.5 g

Frequency of vibration	Time under vibration	Subject No.	Decrement in visual acuity in angles in mts. Both subject & object vibrating	Object stationary subject vibrating
6 Hz	5 mts	1	4.3	2.9
		2	4.1	2.4
		3	4.1	3.6
		4	9.4	0.6
		5	7.1	3.3
	10 mts	1	2.5	2.0
		2	3.8	0.8
		3	3.6	1.6
		4	6.3	0.6
		5	6.0	2.2
8 Hz	5 mts	1	2.9	1.2
		2	3.7	1.3
		3	2.2	2.0
		4	4.2	1.6
		5	2.9	1.8
	10 mts	1	2.6	1.3
		2	4.1	0.4
		3	1.7	1.0
		4	3.9	1.5
		5	3.1	1.0

TABLE IV

Mean decrement in visual acuity with subject and object vibrating as compared to object stationary and subject vibrating.
(Amplitude of vibration 0.5 g)

Frequency of vibration	Time under vibration	Mean decrement in visual acuity in angles in mts. Both subject and object vibrating	Object stationary subject vibrating
6 Hz	5 mts	5.8	2.6
	10 mts	4.8	1.2
8 Hz	5 mts	3.2	1.5
	10 mts	3.1	1.0

TABLE V

Decrement in visual acuity with "Gaps" of Landolt's rings parallel (Horizontal) and perpendicular (Vertical) to the direction of vibration

Time under vibration	Size of ring (opening) in cms	Angle subtended at the eye in mts	Time taken to identify the direction of opening in seconds: Horizontal display of Landolt's rings	Vertical display of Landolt's rings
Basal (no vibration)	0.12	1.50	9.2	8.0
	0.18	3.25	6.1	7.4
Immediate	0.12	1.50	13.2 E2	Can't read
	0.18	2.25	7.2 E0	5.1 E[illegible]
10 minutes	0.12	1.50	11.0 E1	11.0 E[illegible]
	0.12	2.25	3.2 E0	12.0 E[illegible]
20 minutes	0.12	1.50	9.8 E3	14.0 E[illegible]
	0.18	2.25	5.9	10.7
30 minutes	0.12	1.50	9.8 E0	14.5 E[illegible]
	0.18	2.25	5.9	14.5
Basal Immediately after vibration stopped	0.12	1.50	6.0	5.9
	0.12	2.25	5.1	5.2

SUBJECT 1

Distance of the subject from the Landolt's chart = 2.75 metres

Illumination = 7 Lux

Frequency = 6 Hz

Amplitude = 0.5 g

E = Error in identifying

TABLE VI

Decrement in visual acuity with "Gaps" of Landolt's rings parallel (Horizontal) and perpendicular (Vertical) to the direction of vibration.

Time under vibration	Size of ring (opening) in cms	Angle subtended at the eye in mts	Time taken to identify the direction of opening in seconds: Horizontal display of Landolt's rings	Vertical display of Landolt's rings
Basal (no vibration)	0.12	1.50	5.3	5.2
	0.18	2.25	5.1	5.8
Immediate	0.12	1.50	Can't read	Can't read
	0.18	2.25	14.0 E0	16.0 E4
10 minutes	0.12	1.50	13.3 E4	18.8 E4
	0.18	2.25	8.1 E0	7.5 E5
20 minutes	0.12	1.50	12.5 E2	Can't read
	0.18	2.25	6.1 E0	18.3 E1
30 minutes	0.12	1.50	9.3 E3	10.8 E0
	0.18	2.25	5.1	5.0

SUBJECT II

Distance of the subject from the Landolt's chart = 2.75 metres

Illumination = 7 Lux

Frequency = 6 Hz

Amplitude = 0.5 g

E = Error in identifying

TABLE VII

Decrement in visual acuity with "Gaps" of Landolt's rings parallel (Horizontal) and perpendicular (Vertical) to this direction of vibration.

Time under vibration	Size of ring (opening) in cms	Angle subtended at the eye in mts	Time taken to identify the direction of opening in seconds: Horizontal display of Landolt's rings	Vertical display of Landolt's rings
Basal (no vibration)	0.12	1.5	8.3	8.2
	0.18	2.5	7.0	7.0
Immediate	0.12	1.5	15.2	22.5
	0.18	2.5	12.2 E5	15.5 E6
10 minutes	0.12	1.5	13.0 E6	14.4 E4
	0.18	2.25	5.1	5.8
20 minutes	0.12	1.5	14.4 E5	13.8 E4
	0.18	2.5	11.0 E0	10.0 E0
30 minutes	0.12	1.5	11.8 E1	9.7 E2
	0.18	2.5	8.0	6.3 E0
Basal at the end of the vibration	0.12	1.5	11.2 E1	9.7 E2
	0.18	2.5	8.0 E0	6.3 E0

SUBJECT I

Distance of the subject from the Landolt's chart = 2.75 metres

Illumination = 7 Lux

Frequency = 6 Hz

Amplitude = 0.5 g

E = Error in identifying

TABLE VIII

Decrement in visual acuity with "Gaps" of Landolt's rings parallel (Horizontal) and perpendicular (Vertical) to the direction of vibration.

Time under vibration	Size of ring (opening) in cms	Angle subtended at the eye in mts	Time taken to identify the direction of opening in seconds: Horizontal display of Landolt's rings	Vertical display of Landolt's rings
Basal (no vibration)	0.12	1.5	6.4	6.0
	0.18	2.5	5.8	5.0
Immediate	0.12	1.5	7.6	9.0
	0.18	2.5	5.0	6.5
10 minutes	0.12	1.5	6.6	7.6 E1
	0.18	2.5	5.0	5.8
20 minutes	0.12	1.5	6.7	8.3
	0.18	2.5	5.6	5.7
30 minutes	0.12	1.5	6.2	6.2
	0.18	2.5	7.9	6.2

SUBJECT II

Distance of the subject from the Landolt's chart = 2.75 metres

Illumination = 7 Lux

Frequency = 6 Hz

Amplitude = 0.5 g

E = Error in identifying

Results of the studies done with the subject vibrating and object stationary (fixed outside the vibrating platform) reveal that decrement is significantly high when both are vibrating as compared to the situation when only the subject is vibrating. The higher values of decrement in visual acuity are due to phase difference introduced between the vibration of the object and the subject. The vibrational phase of subject gets affected because of the visco-elastic nature of human body. It is also seen that decrement is higher at 6 Hz as compared to 8 Hz.

Studies using Landolt's rings of two different sizes under very low illumination levels reveal that with vertical display the decrement in visual acuity is much higher as compared to the horizontal display. There is a significant increase in the errors in identifying the gaps in Landolt's rings with vertical display. This is a pointer to the possible effects of Gz vibrations on vertical displays, such as vertical scale instruments. It becomes therefore essential to critically assess vertical scale instruments before they are introduced into the low flying aircraft.

Conclusion

The following conclusions are drawn from the present study:

(*a*) The maximum deterioration in visual acuity is in the frequencies of 6 and 12 Hz at an amplitude of 0.5 G.

(*b*) The visual acuity decrement is maximum immediately after the start of vibration and as the vibration exposure is prolonged, there is improvement in visual acuity as compared to the visual acuity level immediately after vibration. However, the improvement noticed after 10 minutes is not significant. It is presumed to be due to the adaptation to vibration environment.

(*c*) The visual acuity deterioration is higher when both subject and object are vibrating as compared to when the object is stationary and the subject alone is vibrating. This is due to difference in the phase of vibration between the object and the subject. At 6 Hz the decrement is more as compared to 8 Hz for the same amplitude.

(*d*) Comparison between the vertical and hori-zontal displays reveal that the deterioration in visual acuity is higher with vertical display as compared to horizontal display for [illegible] vibration. Vertical scale instruments [illegible] require special evaluation under vibration conditions before they can be installed in [illegible] flying aircraft.

Acknowledgement

I am deeply indebted to Dr CA [illegible], Professor of Applied Physics, Institute of Aviation Medicine, IAF for the valuable guidance given to me at every stage and the keen interest taken towards completion of this work.

I am grateful to Air Cdre SP Verma, VM, [illegible] Officer Commanding, Institute of Aviation Medicine for the interest shown towards completion of the project work and for allowing me to use the facilities of the Institute.

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