Dynamic Vision under Vibration and Changes with Curvature of Transparencies

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Abstract

DETERIORATION in dynamic visual acuity under low frequency vibration has been studied. Objects, moving with varying linear speeds in the range of 60–120 cm/sec. and having fixed contrast with the background, were presented to subjects. Threshold size of detection of moving objects show a significant change under vibration. Distortion and curvature in the viewing shield enhances the threshold size of objects. It is observed that low frequency vibration produces visual acuity decrement for static as well as dynamic objects.

Introduction

Static as well as Dynamic visual acuity suffers under low frequency vibration. In aircraft and human operator Interaction system performance is in part dependent upon the ability of operator to see visual displays or targets. Such tasks commonly involve a dynamic element, in which there is a relative motion between the operator and the object observed and acuity can be impaired if the image of the object is not stabilised on the fovea of the retina with spatial accuracy or for sufficient time.

Studies carried out by Dennis[4], Lange and Coermann[8] and Linder[9] reveal that static visual acuity deteriorates by vertical whole body vibration at acceleration of amplitude between 0.1 and 0.75 g and in the frequency range 4-40 Hz. Studies conducted at IAM [6,7,14] found that deteriorating effect was most pronounced at 6 Hz vertical frequency and at 0.5 g amplitude.

There is no reported work on dynamic visual acuity under vibration. Ludvigh and Miller[11] have shown the effect of high speed on the visibility of ground targets from high speed aircraft flying at low altitude. Bhatia[1] and Bhatia and Verghese[2,3] in their laboratory studies have established the relationship between decrement in visibility of moving targets with increase in linear speeds of objects.

In the present study, effects of vibration on dynamic vision has been brought out. Also, the effect of curvature in the viewing shield on the detectibility of targets has been examined.

Material and Methods

Experimental facilities consisted of :—

(i) a hydraulic vertical vibration simulator, simulating vertical vibrations in the frequency range 2–15 Hz and with variable amplitudes. Frequency of vibration was kept at 6 Hz whereas amplitude was maintained constant at 0. 5 g.

(ii) A rotating drum arrangement. Drum of 22. 7 cm diameter was driven by a D. C. motor whose speed could be varied by varying the voltage.

(iii) A mirror arrangement to simulate large distances.

For moving objects with known contrasts between the objects and the background, white cards of dimension 14. 5 cm × 15cm with reflectance of 94% were

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employed, on which small strips of objects of varying width were pasted. Four horizontal pair of lines equi distant from each other separated by 2 cm. gap were drawn and obejcts cut from a paper with 64% reflectance were pasted. Objects could be put in any of the four positions but in no card all the columns were filled or kept empty. Cards could be fixed on the rotating drum so that objects with uniform contrast with the background and moving with known linear velocities were simulated.

To keep the viewing area and viewing time constant a slit of dimension 13 cm x 10.5 cm was placed in front of the rotating drum, so that observer was seeing the objects through the slit for a fixed duration only. Uniform light was cast on the cards attached to drums and level of illumination at the card was maintained at 100 lux.

Experiments were divided as follows :—

(i) Determining threshold of detection of moving objects at distances of 8, 12 and 20 meters from the observer for various linear speeds of objects.

(ii) Determining the threshold of detection of moving objects for same distances and speeds under conditions of vibration of 6 Hz at 0. 5 g amplitude. Experimental procedure consisted of showing different size objects to the observer sitting in the cockpit of vibration simulator, viewing objects in the mirror placed in front of the viewing shield.

Keeping the distance fixed and illumination level constant between the objects and the background, objects were presented at linear speeds of 60 cm/sec., 85cm/sec and 120 cm/sec, and detectibility determined on the basis of correct answers. Correctness was based on whether or not the subject is able to tell in what position the objects are placed. A 90% correct answer for a particular object size and object speed, based on probit analysis was taken as the threshold of detection for that particular condition.

Thresholds were determined for distances of 8, 12 and 20 mtrs. without vibration. Similar procedure was followed for determining threshold of detection under vibration conditions for a distance of 20 meters.

Distortion and curvatures in the viewing shield could alter the detectibility of moving objects quite significantly.

To study the effects of curvature and distortion on threshold of detection of moving objects, experiments were done adopting the procedure explained earlier and using curved viewing shields. Objects in these experiments were black strips of paper of varying widths placed on the cards in various positions. Since it was envisaged that object size could become very large if low contrast between the objects and its surrounding was maintained, highest possible contrast was maintained. A conversion factor from maximum contrast to contrast employed earlier was determined by comparing threshold of detection for objects moving at 60 cm/sec. linear speed placed at 20 meters from the observer.

Three healthy subjects with 6/6 vision without glasses and normal accommodation were employed for the study. Subjects were trained in perceiving the moving objects by giving trial runs for distance of 1,2 and 4 meters at speeds of 60 cm/sec.

Results

Results are given in Table I—VI. Threshold sizes of objects given in the tables are average values for three subjects :—

TABLE I

Decrement in visual acuity at four different frequencies, at different times under vibration (from earlier study [14])

Time under vibration	Mean decrement in visual acuity in angles in minutes			
	6 Hz	8 Hz	10 Hz	12 Hz
Immediate	6.9	4.3	5.0	5.2
10 minutes	6.6	5.0	4.6	6.2
20 minutes	5.6	4.2	4.9	5.4
30 minutes	5.4	4.0	4.9	5.6

TABLE II

Threshold of detection of moving object without vibration

Sl. No.	Speed cm/sec.	Distance m.	Linear object size mm
1.	85	8	5.82
2.	60	12	5.57
3.	60	20	15.27
4.	85	20	18.71
5.	120	20	30.48

TABLE III

Threshold of detection of moving objects without and with vibration (frequency 6 Hz, 0.5 g amp) Distance 20 meters

Sl. No.	Speed cm/sec.	With vibration Object size mm	Without vibration Object size mm	Percentage increse in Object size with vibration
1.	60	19.78	15.27	29.5
2.	85	24.33	19.71	30.5
3.	120	43.15	30.48	41.6

TABLE IV

Threshold size of objects with 100% contrast, distance–20 meters, Illuminance– 100 Lux, speed of objects – 60 cm/sec. No vibration

S. No.	Object size mm	Average mm
Subject 1	7.40	7.90
Subject 2	8.40	

Threshold sizes of object with lower contrast for similar conditions of distance, Illuminance, and speed as given in table III is 15.23 mm.

$$\text{Conversion factor is } \frac{15.27}{7.90} = 1.9329$$

Hence for 100% contrast threshold size of object

$$\text{with vibration is } \frac{19.78}{1.9329} = 10.23 \text{ mm.}$$

TABLE V

Details about windshields employed

	Thickness cm	Curvature (h) cm	Radius of curvature cm
Wind shield I	0.48	8.90	30.47
Wind shield II	0.58	13.16	24.58
Wind shield III	0.63	11.77	26.40

TABLE VI

Threshold size of detection of moving objects with and without vibration

Sl. No.	Curvature cm	Object size without vibration mm	Object size with vibration mm	Percentage increase in object size
1.	No curvature	7.90	10.23	29.5
2.	8.90	16.36	26.13	59.7
3.	11.77	11.73	17.70	50.9
4.	13.16	11.16	20.80	86.4

Vibration condition : Frequency - 6 Hz
: Amplitude - 0.5 g.

Distance of viewing : 20 meter, linear speed of object-60 cm/sec

Illumination : 100 lux

Discussion

(i) From table 1, it is seen that static visual acuity shows a maximum deterioration at 6 Hz and its harmonic at 12 Hz, although the effect is more pronounced at 6 Hz. Resonance frequency of eye balls is much higher compared to whole body resonance. Since there is a maximum transmissibility of vibration from seat to head, deterioration is expected to be maximum at whole boby resonance. Griffin[5] reported that in whole body vibration experiments change in the visual acuity were dependent on relative motion of eye and head; extent of the effect being dependent on vibration frequency. Low frequency vibrations aport from being objectionable physically, show definite psychophysiological effects[17]. Sheenberger[13] has reported that performance decrement in two dimentional compensatory tracting task and visual deterioration of reaction time around whole body resonance. Thus deterioration in static visual acuity at 6 Hz is in conformity with others findings.

(ii) For moving objects, with increasing speeds and distance (between the targets and observer), threshold sizes increase indicating thereby a decrease in detectibility. But this increase in the object sizes is not uniform. For change in observer's distance from 12 to 20 meters *i.e.* 1.7 fold increase in distance, object size increases 2.7 fold. Similarly, for a fixed object speed of 85cm/sec increase in distance from 8 meters to 20 meters the changes are not proportionate, a 2.5 fold increase in distance gave rise to 3.2 fold increase in object sizes.

For a fixed distance of 20 meters, increase in object speeds from 60 cm/sec and 85 cm/sec to 120 cm/sec do not show proportionate changes.

The results are not in confirmity with earlier work [2] where a constancy in object sizes was found for a distance range of 1–5 meters. This is probably attributable to the larger distances in the present series.

(iii) Under vibration exposure, larger object sizes are required for detection for same speeds and distance. At lower linear speeds of 60 and 85 cm/sec, a 30 percent increase in object size was required where as at the linear speed of 120 cm/sec, increase required was nearly 40 percent. In fast moving aircraft at lower altitude the detection of objects will seem to become progressively difficult due to vibration.

(iv) Curvature and/or distortion in the viewing shields causes greater decrement in the visibility of moving objects. From Table VI it is seen that the threshold size of detection of objects increases with increase in the curvature. For plane windshields, vibration produced around 30% increase in object size whereas with curvatures increase in threshold size of objects was over 50%. This clearly shows the necessity of plane and distortion-free wind shields.

Conclusion

Static as well as dynamic visual acuity shows a significant deterioration under vertical vibration at 6 Hz and amplitude of 0.5 g. This lends support to the school of thought that in seated human, visual as well as other performances depend upon transmissibility of vibration from seat to different body parts and happens to be maximum near whole body resonance.

In low altitude high speed flying, vibrations are regularly encountered. In view of the effect of curved and distorted wind shields on detectibility of moving objects it is proposed that as far as possib curvature and distortion free wind shields be used f viewing. Also, devices which will reduce t transmissibility of vibration around resonance m prove to be helpful in improving visual performan under whole body vibration.

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