Data base structure

Direction / Task	Frequency ranges: Low (< 1 Hz)			Medium (1 to 6 Hz)			High (6 to 200 hZ)			Total
	x	y	z	x	y	z	x	y	z	
Tracking (e.g. sidestick)	0	0	3	0	1	12	0	0	3	19
Manipulating (e.g. selecting)	0	0	0	0	0	1	0	0	0	1
Communication	0	0	0	0	0	3	0	0	1	4
Reading and data process. (C/L, display)	2	2	2	2	3	14	1	1	4	31
Well being, fatigue, alertness	0	0	0	1	1	4	1	1	4	12
Total	2	2	5	3	5	34	2	2	12	67

2

- Frequency : Low
- Axis : x
- Task or measure : tracking

3

- Frequency : Low
- Axis : y
- Task or measure : tracking

4

- Frequency : Low
- Axis : z
- Task or measure : tracking

Effects of Low Frequency Whole-Body Vibration on Tracking Performance

Ref. 23

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: ø 0.15 Hz pseudo random Magnitude: 0.151-0.271 rms ms^{-2} Axis : z Input: by a seat six experiment. blocks: control run, five vibration conditions (three levels of whole-body random vibration, two lowest vibration levels+randomly occuring impacts) in randomised order
Threshold of acceptability	---
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (z-axis vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	12 male subjects 10 army officers, 2 civilians experienced with vibration experiments
Task/activities description : input details (display size, position), performance measures, training	Human performance: tracking task
Comments	For the random vibration inputs the mean absolute tracking error increases significantly linearly with rms acceleration. The additional error due to the impacts increases in proportion to the peak acceleration raised to the power 2.5.

References:

Hall, L. C. The effect of low frequency whole body vibration and impacts on human tracking performance. Journal of Low Frequency Noise & Vibration, 4(4), 1985, pp. 154-162.

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Other ref.

Effects of Display Collimation and Vibration Waveform at Frequencies From 0.5 to 10 Hz on Manual Control Performance

Ref. 46

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 0.5 Hz sinusoidal; 0.5-10.0 Hz 1/3 octave band random Magnitude: 1.6 rms ms^{-2}; 2.1 rms ms^{-2} Axis : z Input: by a seat two exp. sessions: 1. sinusoidal, 2. 1/3 octave band random, randomised order in each group, 1 min. warming-up, 16 runs à 150 sec
Threshold of acceptability	---
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (electro-hydraulic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	16 male subjects 18-32 years two independent groups of 8 subjects each (collimination and no collimintaion)
Task/activities description : input details (display size, position), performance measures, training	<u>Human performance</u>: combined continuous tracking and discrete target acquisition task (two axis pursuit tracking with simplified version of aircrafts dynamics plus button pressing to indicate when on target)
Comments	Without display collimination both types of vibration significantly disrupt performance at all frequencies. Colliminating the display removes the disruption at frequencies above 1.6 Hz. With random vibration collimination also reduces the effect of vibration at frequencies below 1.6 Hz. Differences between the effects of sinusoidal and random vibration occur only with vibration of 2.0-2.5 Hz. When a operator is required to perform continuous manual control during low frequency vibration exposure, performance impairments due to vibration may be reduced by colliminating relevant displays.

References: McLeod, R.W. & Griffin, M.J. Effects of whole-body vibration waveform and display collimation on the performance of a complex manual control task. Aviation, Space and Environmental Medicine, 61, 1990, pp. 211-219.

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Other ref.

Effects of Vibration Frequency from 0.5 to 5.0 Hz on Manual Control Performance

Ref. 24

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 0.5-5.0 Hz Magnitude: 2.0 rms ms^{-} Axis : z (sinusoidal) Input: by a seat two experimental sessions á 13 3-min. runs each: one warming up, one without, 11 with vibration, randomised orders
Threshold of acceptability	---
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (electro-hydraulic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	8 male subjects 22-28 years
Task/activities description : input details (display size, position), performance measures, training	<u>Human performance</u>: combined continuous and discrete pursuit tracking task; Subjects are highly trained (at least 10 practice sessions à 3-min.).

Comments Disruption of continuous performance is approximately constant at about 5% from 0.5 to 3.15 Hz and increases from 4.0 Hz up to 15% at 5 Hz. A visual mechanism is assumed to account for the increased disruption at higher frequencies. The vibration effect on discrete task is not disrupted by the frequency independently from the effects on the continuous task.

References: McLeod, R.W. & Griffin, M.J. Performance of a complex manual control task during exposure to whole-body vertical vibration between 0.5 and 5.0 Hz. Ergonomics, 31, 1988, pp. 1193-1203.

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Other ref.

5

- Frequency : Low
- Axis : x
- Task or measure : manipulating

6

- Frequency : Low
- Axis : y
- Task or measure : manipulating

7

- Frequency : Low
- Axis : z
- Task or measure : manipulating

8

- Frequency : Low
- Axis : x
- Task or measure : communication

9

- Frequency : Low
- Axis : y
- Task or measure : communication

10

- Frequency : Low
- Axis : z
- Task or measure : communication

11

- Frequency : Low
- Axis : x
- Task or measure : reading and data process

Effects of horizontal low frequency vibration on reading

Ref. 7

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 0 - 1 Hz Axis : x (pitching) y (twisting) z (rolling) Magnitude : 2 - 5 m/s^2 Rotation : +/- 30° Translation : +/- 10 cm Input: by a chair
Threshold of acceptability	
Effects of exposure duration	Disruptive effects (increase of reading time) appear from the beginning of the movement and increase with frequency.
Conditions : lab, field study (aviation or other)	Lab for aviation study
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	Pilots
Task or measure/activities description : input details (display size, position), performance measures, training	Alpha numeric characters reading Task or measures
Comments	Pitching and twisting are more disruptive movements than rolling (reading time increase of **60%**) Twisting and pitching are more disruptive movements than rolling (reading time increase of **60%**) Rolling is less disruptive movements than twisting and pitching (reading time increase of **27%**)

References: MALVACHE (M.).: Les laboratoires français effectuant des études de vibrations en relation avec l'être humain: le Laboratoire d'automatique indus. et hum. de l'Univ. de Valenciennes. In: Les vibrations industrielles. Doc INRS. Mars 1983. Pp 135-136.

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Other ref.

Effects of horizontal low and medium frequency vibration on reading

Ref. 3

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 0.5 - 10 Hz Random Axis : x and y Magnitude : 1.0 and 1.25 m/s^2 Input: by a chair with backrest attached to vibration table
Threshold of acceptability	
Effects of exposure duration	Horizontal vibration of seated subjects cause a maximum measured reduction in the speed of reading at 4 Hz, to a lesser extent at 3.15 Hz and 5 Hz.
Conditions : lab, field study (aviation or other)	Lab
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	16 subjects (8 male, 8 female), aged from 19 to 30 years
Task or measure/activities description : input details (display size, position), performance measures, training	Reading of 68 sheets of paper containing a photocopy of the first leader article in an edition of the london Times. Reading speed is calculated from the number of syllables read in a 30s period.
Comments	Horizontal medium frequency vibration have a more important effect on reading speed than lateral medium frequency vibration (probably because of transmission of vibrations by backrest seat).

References: GRIFFIN (M.J.); HAYWARD (R.A.): Effects of horizontal whole-body vibration on reading. In: Applied Ergonomics, 1994, Vol 25, n°3, pp. 165-169.

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Other ref.

12

- Frequency : Low
- Axis : y
- Task or measure : reading and data process

Effects of horizontal low frequency vibration on reading

Ref. 7

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 0 - 1 Hz Axis : x (pitching) y (twisting) z (rolling) Magnitude : 2 - 5 m/s^2 Rotation : +/- 30° Translation : +/- 10 cm Input: by a chair
Threshold of acceptability	
Effects of exposure duration	Disruptive effects (increase of reading time) appear from the beginning of the movement and increase with frequency.
Conditions : lab, field study (aviation or other)	Lab for aviation study
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	Pilots
Task or measure/activities description : input details (display size, position), performance measures, training	Alpha numeric characters reading Task or measures
Comments	Pitching and twisting are more disruptive movements than rolling (reading time increase of **60%**) Twisting and pitching are more disruptive movements than rolling (reading time increase of **60%**) Rolling is less disruptive movements than twisting and pitching (reading time increase of **27%**)

References: MALVACHE (M.).: Les laboratoires français effectuant des études de vibrations en relation avec l'être humain: le Laboratoire d'automatique indus. et hum. de l'Univ. de Valenciennes. In: Les vibrations industrielles. Doc INRS. Mars 1983. Pp 135-136.

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Other ref.

Effects of horizontal low and medium frequency vibration on reading

Ref. 3

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 0.5 - 10 Hz Random Axis : x and y Magnitude : 1.0 and 1.25 m/s^2 Input: by a chair with backrest attached to vibration table
Threshold of acceptability	
Effects of exposure duration	Horizontal vibration of seated subjects cause a maximum measured reduction in the speed of reading at 4 Hz, to a lesser extent at 3.15 Hz and 5 Hz.
Conditions : lab, field study (aviation or other)	Lab
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	16 subjects (8 male, 8 female), aged from 19 to 30 years
Task or measure/activities description : input details (display size, position), performance measures, training	Reading of 68 sheets of paper containing a photocopy of the first leader article in an edition of the london Times. Reading speed is calculated from the number of syllables read in a 30s period.
Comments	Horizontal medium frequency vibration have a more important effect on reading speed than lateral medium frequency vibration (probably because of transmission of vibrations by backrest seat).

References: GRIFFIN (M.J.); HAYWARD (R.A.): Effects of horizontal whole-body vibration on reading. In: Applied Ergonomics, 1994, Vol 25, n°3, pp. 165-169.

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Other ref.

13

- Frequency : Low
- Axis : z
- Task or measure : reading and data process

Effects of horizontal low frequency vibration on reading

Ref. 7

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 0 - 1 Hz Axis : x (pitching) y (twisting) z (rolling) Magnitude : 2 - 5 m/s^2 Rotation : +/- 30° Translation : +/- 10 cm Input: by a chair
Threshold of acceptability	
Effects of exposure duration	Disruptive effects (increase of reading time) appear from the beginning of the movement and increase with frequency.
Conditions : lab, field study (aviation or other)	Lab for aviation study
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	Pilots
Task or measure/activities description : input details (display size, position), performance measures, training	Alpha numeric characters reading Task or measures
Comments	Pitching and twisting are more disruptive movements than rolling (reading time increase of **60%**) Twisting and pitching are more disruptive movements than rolling (reading time increase of **60%**) Rolling is less disruptive movements than twisting and pitching (reading time increase of **27%**)

References: MALVACHE (M.).: Les laboratoires français effectuant des études de vibrations en relation avec l’être humain: le Laboratoire d’automatique indus. et hum. de l’Univ. de Valenciennes. In: Les vibrations industrielles. Doc INRS. Mars 1983. Pp 135-136.

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Other ref.

Comparison of Display, Whole-Body and Simultaneous Whole-Body-and-Display Vibration on Reading Performance

Ref. 27

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 0.5-5.0 Hz Magnitude: 1.0-2.5 rms ms^{-2} Axis : z (sinusoidal) Input: by a seat experimental conditions: 11 frequencies at 5 magnitudes (55 stimuli), three blocks: 1. display, 2. subject, 3. subject+display vibrating, randomised order
Threshold of acceptability	---
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (hydraulic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	15 male subjects all under 30 years
Task/activities description : input details (display size, position), performance measures, training	Human performance: numeral reading of a CRT display (characters subtend 5 min arc and 12 min arc at 0.75 m)
Comments	For frequencies below 4 Hz display vibration produces the largest performance decrements and whole-body-and-display vibration the least. Whole-body vibration with a stationary display produces significantly worse performance than simultaneous vibration of both observer and display but significantly better performance than display vibration alone. The variations in performance with frequency and viewing condition are consitent across all vibration magnitudes.

References:

Moseley, M.J. & Griffin, M.J. Effects of display vibration and whole-body vibration on visual performance. Ergonomics, 29, 1986, pp. 977-983.

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Other ref.

Comparison of Display, Whole-Body and Simultaneous Whole-Body-and-Display Vibration on Reading Performance

Ref. 27

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 0.5-5.0 Hz Magnitude: 1.0-2.5 rms ms^{-2} Axis : z (sinusoidal) Input: by a seat experimental conditions: 11 frequencies at 5 magnitudes (55 stimuli), three blocks: 1. display, 2. subject, 3. subject+display vibrating, randomised order
Threshold of acceptability	---
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (hydraulic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	15 male subjects all under 30 years
Task/activities description : input details (display size, position), performance measures, training	Human performance: numeral reading of a CRT display (characters subtend 5 min arc and 12 min arc at 0.75 m)
Comments	For frequencies below 4 Hz display vibration produces the largest performance decrements and whole-body-and-display vibration the least. Whole-body vibration with a stationary display produces significantly worse performance than simultaneous vibration of both observer and display but significantly better performance than display vibration alone. The variations in performance with frequency and viewing condition are consitent across all vibration magnitudes.

References:

Moseley, M.J. & Griffin, M.J. Effects of display vibration and whole-body vibration on visual performance. Ergonomics, 29, 1986, pp. 977-983.

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Other ref.

14

- Frequency : Low
- Axis : x
- Task or measure : well being, fatigue, alertness

15

- Frequency : Low
- Axis : y
- Task or measure : well being, fatigue, alertness

16

- Frequency : Low
- Axis : z
- Task or measure : well being, fatigue, alertness

17

- Frequency : Medium
- Axis : x
- Task or measure : tracking

18

- Frequency : Medium
- Axis : y
- Task or measure : tracking

Long-Term Effects of Vibration on Complex Psychomotor Performance

Ref. 12

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 2, 5 Hz (acceleration power peak) Magnitude: 0, 0.12, 0.16 rms G Axis : z, y (random) Input: by a seat experiment. blocks.: two frequencies at three vibration levels (one control), duration per block: 6 h, counterbalanced order of blocks
Threshold of acceptability	---
Effects of exposure duration	Improved tracking performance across experimental blocks reflects an adjustment to vibration. Improved tracking performance during the second and near the end of 6 h of one block indicates the danger of extrapolating long-term performance data from short exposures.
Conditions : lab, field study (aviation or other)	Lab (electro-hydraulic vibration simulator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	12 cadets of the U.S. Air Force Advanced Reserve Officers Training Corps, having flight experience two independent experimental groups (N=6) for each frequency
Task/activities description : input details (display size, position), performance measures, training	Human performance: continuous tracking, visual reaction time (response to a series of red and green lights), and auditory reaction time (response to a change in the frequency of an auditory signal); performance measures are taken during the first 45 min. of each h of a 6-h block; three 2 h practice sessions before the main experiment
Comments	All vibration conditions lead to significant decline in tracking performance when compared with control conditions. Tracking performance on the horizontal axis is consistently better that that on the vertical axis. The 5 Hz spectrum is the most detrimental to tracking performance. Warning light performance is not affected by vibration. Auditory signal performance is not impaired at all: only one out of every 200 critical signal is not detected.

References:

Holland, C.L. Performance effects of long-term random vertical vibration. Human Factors, 9, 1967, pp. 93-104.

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Other ref.

19

- Frequency : Medium
- Axis : z
- Task or measure : tracking

Effects of vertical medium frequency vibration on tracking

Ref. 5.2

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 5 Hz Sinusoidal Axis : z 0.25 Peak G Input: by a chair with a widden seat
Threshold of acceptability	
Effects of exposure duration	At 5Hz vibration, large decrements are to be expected in tracking performance, at least for short-term exposure.
Conditions : lab, field study (aviation or other)	Lab
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	10 male military members of the US Air Force, volunteers, ranging from 23 to 30 years
Task or measure/activities description : input details (display size, position), performance measures, training	Human performance: - tracking Task or measures - complex reaction time with calculating

Comments High level noise (100 - 110 dB) when combined with vibration produce more adverse effects than either of the stressors alone.

References: Harris, C.S. & Sommer, H.C. (1973). Interactive effects of intense noise and low-level vibration on tracking performance and response time. *Aerospace Medicine*, 44, 1013-1016.

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Other ref.

Effects of vertical medium frequency vibration on tracking

Ref. 1.1

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 5 Hz Sinusoidal Axis : z 0.30 Peak G Input: by a chair attached to vibration table Duration : 35 min
Threshold of acceptability	
Effects of exposure duration	Exposure to vibration causes a marked impairment of visual acuity and tracking ability. These vibrations increase reaction time to a green light extinction.
Conditions : lab, field study (aviation or other)	Lab for aviation study
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	10 male military personnel
Task or measure/activities description : input details (display size, position), performance measures, training	Human performance : Tracking ability, mental arythmetic, reaction time, visual acuity, voice comm. Physiological measures : body temperature, heart rate, weight loss, subjective ratings of the stress.
Comments	Combined-stress condition (heat, noise and vibrations) is less disturbing to the subjects and their performance than is vibration alone.

References: GRETHER (W.F.) et al.: Effects of combined heat, noise and vibration stress on human performance and physiological functions. In: Aerospace Medicine, 1971, October, pp. 1092-1097.

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Other ref.

Long-Term Effects of Vibration on Complex Psychomotor Performance

Ref. 12

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 2, 5 Hz (acceleration power peak) Magnitude: 0, 0.12, 0.16 rms G Axis : z, y (random) Input: by a seat experiment. blocks.: two frequencies at three vibration levels (one control), duration per block: 6 h, counterbalanced order of blocks
Threshold of acceptability	---
Effects of exposure duration	Improved tracking performance across experimental blocks reflects an adjustment to vibration. Improved tracking performance during the second and near the end of 6 h of one block indicates the danger of extrapolating long-term performance data from short exposures.
Conditions : lab, field study (aviation or other)	Lab (electro-hydraulic vibration simulator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	12 cadets of the U.S. Air Force Advanced Reserve Officers Training Corps, having flight experience two independent experimental groups (N=6) for each frequency
Task/activities description : input details (display size, position), performance measures, training	<u>Human performance</u>: continuous tracking, visual reaction time (response to a series of red and green lights), and auditory reaction time (response to a change in the frequency of an auditory signal); performance measures are taken during the first 45 min. of each h of a 6-h block; three 2 h practice sessions before the main experiment
Comments	All vibration conditions lead to significant decline in tracking performance when compared with control conditions. Tracking performance on the horizontal axis is consistently better that that on the vertical axis. The 5 Hz spectrum is the most detrimental to tracking performance. Warning light performance is not affected by vibration. Auditory signal performance is not impaired at all: only one out of every 200 critical signal is not detected.

References:

Holland, C.L. Performance effects of long-term random vertical vibration. Human Factors, 9, 1967, pp. 93-104.

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Other ref.

Effects of Vibration Duration up to 60 Minutes on Manual Control Performance

Ref. 19

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: static or 4 Hz Magnitude: 1.2 rms ms^{-2} Axis : z Input: by a seat two experimental runs à 75 min: 1. static condition, 2. 4 Hz sinusoidal vibration for 60 min. followed by no vibration (15 min.)
Threshold of acceptability	---
Effects of exposure duration	Vibration does not alter the overall effect of duration.
Conditions : lab, field study (aviation or other)	Lab (electro-dynamic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	8 subjects two independent groups for both controls (N=4)
Task/activities description : input details (display size, position), performance measures, training	<u>Human performance</u>: continuous zero-oder tracking in one axis for 75 minutes, using isotonic or isometric side-arm controls with no arm support; Two-1 h practice sessions before the main experiment
Comments	After 15 min.continuous performance there are large increases in overall error variance in both static and vibration conditions. This is due to large increases in response lags and suppression of coherent responses by the subjects due to the underarousing nature of the task (reduced level of arousal).

References:

Lewis, C.H. & Griffin, M.J. Mechanisms of the effects of vibration frequency, level, and duration on continuous manual control performance. Ergonomics, 22, 1979a, pp. 855-889.

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Other ref.

Ref. 5

Effects of Combined Noise, Vibration and Heat on Physiological, Biochemical, Cognitive, and Subjective Parameters

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 5 Hz Magnitude: 0.30 G (peak) Axis : z (sinusoidal) Input: by a chair other stressors: heat (22, 48 º C), noise (80, 105 dB) four experiment. combinations à 95 min.: 1. control, 2. vibration only, 3. vibration+heat, 4. vibration+ heat+noise
Threshold of acceptability	---
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (mechanical vibration table)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	12 male military personnel six of the 12 participated in an earlier experiment, 6 are new experienced subjects: 2 hours of retraining on performance tests; new subjetcs: 4 hours of training
Task/activities description : input details (display size, position), performance measures, training	Physiological measures: skin and rectal temperature, heart rate, weight loss, urine (collected for 24 hours), accelerometer Human performance: tracking, choice reaction time, communication test of logical alternatives, mental arithmetic, visual acuity Subjective ratings: stress severity scale, semantic differential regarding severity and intrusiveness of the stress conditions
Comments	There are significant effects for skin and rectal temperatures, heart rate and weight loss probably caused by heat. However, effects due to heat cannot be isolated since there was no single heat condition. On tracking and reaction time tests the greatest impairment of performance is producred by single vibration. The combination of all stressors produces antagonistic rather than additive performance effects. Accelerometer measures indicate that transmissibility of vibration is not altered by heat or noise. Subjective ratings of stress severity progressively increase with the number of stressors; ratings of intrusiveness does not show such a trend.

References:

Grether, W.F. et al. Further study on combined heat, noise and vibration stress. Aerospace Medicine, 43, 1972, pp. 641-645.

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Other ref.

Effects of Vibration Exposure Duration up to 202 Minutes on Complex Psychomotor Performance

Ref. 25

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 4 Hz static, band random Magnitude: 1.4 rms ms^{-} Axis : z Input: by a chair two separate experimental sessions à 202 min
Threshold of acceptability	---
Effects of exposure duration	Performance significantly deteriotes with duration in all conditions and vibration does not alter the time dependence. Performance on session 2 is significantly better than on session 1 (training effect).
Conditions : lab, field study (aviation or other)	Lab (electro-hydraulic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	14 subjects two independent groups of seven subjects each (vibration and no vibration)
Task/activities description : input details (display size, position), performance measures, training	Human performance: continuous tracking in two axes using simplified aircraft dynamics plus button pressing to indicate when on target; Subjects are highly trained in short duration performance.
Comments	There is clearly an adaptation to the duration of performance even though subjects are trained at the tracking task for short durations. The effect of duration is attributed to muscular and mental fatigue. A vibration exposure above „fatigue-decreased-profiency“ boundary defined in ISO 2631 does not effect performance relative to no vibration performance.

References: McLeod, R.W. & Griffin, M.J. (1989). A study of the effect of the duration of exposure to whole-body vibration on the performance of a complex task. Cited from: Griffin, M.J. (1990). Handbook of human vibration.

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Other ref.

Effects of Vibration Frequency from 0.5 to 5.0 Hz on Manual Control Performance

Ref. 24

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 0.5-5.0 Hz Magnitude: 2.0 rms ms^{-} Axis : z (sinusoidal) Input: by a seat two experimental sessions á 13 3-min. runs each: one warming up, one without, 11 with vibration, randomised orders
Threshold of acceptability	---
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (electro-hydraulic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	8 male subjects 22-28 years
Task/activities description : input details (display size, position), performance measures, training	<u>Human performance</u>: combined continuous and discrete pursuit tracking task; Subjects are highly trained (at least 10 practice sessions à 3-min.).
Comments	Disruption of continuous performance is approximately constant at about 5% from 0.5 to 3.15 Hz and increases from 4.0 Hz up to 15% at 5 Hz. A visual mechanism is assumed to account for the increased disruption at higher frequencies. The vibration effect on discrete task is not disrupted by the frequency independently from the effects on the continuous task.

References: McLeod, R.W. & Griffin, M.J. Performance of a complex manual control task during exposure to whole-body vertical vibration between 0.5 and 5.0 Hz. Ergonomics, 31, 1988, pp. 1193-1203.

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Other ref.

Effects of Vibration on Manual Control Performance

Ref. 17

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 3, 5, 8 Hz Magnitude: 0, 0.43, 0.87, 1.73 rms ms^{-2} Axis : z Input: by a seat four experimental sessions: combined sinusoidal components at three amplitudes each at three levels of control stiffness: 0, 0.08, 0.16 kg cm^{-1}, one zero vibration condition
Threshold of acceptability	---
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (electro-magnetic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	12 male subjects
Task/activities description : input details (display size, position), performance measures, training	<u>Human performance</u>: zero-order tracking, side-arm control with no arm-rest, 1.1 m viewing distance (dependent variables: information channel capacity, frequency dependent error); one practice session

Comments There is no significant difference between performance at the three stiffness levels with no vibration. Increasing the stiffness of the control reduces the disruption due to vibration which is due to an increased channel capacity during vibration. Vibration breakthrough contributes only a small proportion of total error, greatest disruption occurs at tracking frequencies below 4 Hz.

References: Lewis, C. H. & Griffin, M. J. The effects of vibration on manual control performance. Ergonomics, 19, 1976, pp. 203-216.

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Other ref.

Comparison of Display, Whole-Body and Simultaneous Whole-Body-and-Display Vibration on Reading Performance

Ref. 27

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 0.5-5.0 Hz; Magnitude: 1.0-2.5 rms ms^{-2}; Axis : z (sinusoidal); Input: by a seat; experimental conditions: 11 frequencies at 5 magnitudes (55 stimuli), three blocks: 1. display, 2. subject, 3. subject+display vibrating, randomised order
Threshold of acceptability	---
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (hydraulic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	15 male subjects all under 30 years
Task/activities description : input details (display size, position), performance measures, training	Human performance: numeral reading of a CRT display (characters subtend 5 min arc and 12 min arc at 0.75 m)

Comments For frequencies below 4 Hz display vibration produces the largest performance decrements and whole-body-and-display vibration the least. Whole-body vibration with a stationary display produces significantly worse performance than simultaneous vibration of both observer and display but significantly better performance than display vibration alone. The variations in performance with frequency and viewing condition are consitent across all vibration magnitudes.

References:

Moseley, M.J. & Griffin, M.J. Effects of display vibration and whole-body vibration on visual performance. Ergonomics, 29, 1986, pp. 977-983.

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Other ref.

Interaction of Control Gain and Vibration with Manual Control Performance

Ref. 18

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: static or 4 Hz sinusoidal Magnitude: 0.75 rms ms^{-2} Axis : z Input: by a seat four experimental blocks with different control gain conditions: isometric and isotonic joysticks and knobs with gains from 12.5-50 cm/radian for isotonic and 2.5-10cm/radian for isometric controls
Threshold of acceptability	---
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (electro-dynamic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	4 male subjects 18-26 years right-handed
Task/activities description : input details (display size, position), performance measures, training	Human performance: zero order tracking in one axis with four different controls (isotonic (=displacement) and isotronic (= force) joysticks and knobs); one practice session of 4.5 h (static condition)
Comments	There is a significant interaction between control gain and vibration: the optimum control gain for minimizing tracking error under a given vibration condition is likely to be lower than that for minimizing error under static conditions due to increases in vibration-correlated error and non-linear response which both tend to depend on control gain.

References:

Lewis, C. H. & Griffin, M. J. The interaction of control gain and vibration with continuous manual control performance. Journal of Sound and Vibration, 55, 1977, pp. 553-562.

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Other ref.

Interaction of Control Gain and Vibration with Manual Control Performance

Ref. 18

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: static or 4 Hz sinusoidal Magnitude: 0.75 rms ms^{-2} Axis : z Input: by a seat four experimental blocks with different control gain conditions: isometric and isotonic joysticks and knobs with gains from 12.5-50 cm/radian for isotonic and 2.5-10cm/radian for isometric controls
Threshold of acceptability	---
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (electro-dynamic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	4 male subjects 18-26 years right-handed
Task/activities description : input details (display size, position), performance measures, training	Human performance: zero order tracking in one axis with four different controls (isotonic (=displacement) and isotronic (= force) joysticks and knobs); one practice session of 4.5 h (static condition)
Comments	There is a significant interaction between control gain and vibration: the optimum control gain for minimizing tracking error under a given vibration condition is likely to be lower than that for minimizing error under static conditions due to increases in vibration-correlated error and non-linear response which both tend to depend on control gain.

References: Lewis, C. H. & Griffin, M. J. The interaction of control gain and vibration with continuous manual control performance. Journal of Sound and Vibration, 55, 1977, pp. 553-562.

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Other ref.

Effects of vertical medium frequency vibration on tracking

Ref. 1.3

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 5 Hz Sinusoidal Axis : z 0.30 Peak G Input: by a chair attached to vibration table Duration : 35 min
Threshold of acceptability	
Effects of exposure duration	Exposure to vibration causes a marked impairment of visual acuity and tracking ability.
Conditions : lab, field study (aviation or other)	Lab for aviation study
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	10 male military personnel
Task or measure/activities description : input details (display size, position), performance measures, training	Human performance : Tracking ability, mental arythmetic, reaction time, visual acuity, voice comm. Physiological measures : body temperature, heart rate, weight loss, subjective ratings of the stress.

Comments Combined-stress condition (heat, noise and vibrations) is less disturbing to the subjects and their performance than is vibration alone.

References: GRETHER (W.F.) et al.: Effects of combined heat, noise and vibration stress on human performance and physiological functions. In: Aerospace Medicine, 1971, October, pp. 1092-1097.

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Other ref.

20

- Frequency : Medium
- Axis : x
- Task or measure : manipulating

21

- Frequency : Medium
- Axis : y
- Task or measure : manipulating

22

- Frequency : Medium
- Axis : z
- Task or measure : manipulating

Effects of Broadband Noise and Complex Waveform Vibration on Cognitive Performance

Ref. 10

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 2.6, 4.1, 6.3, 10, 16 Hz Magnitude: 0.36 rms G quasi-random sum-of-sines vibrations Axis : z Input: by a seat other stressor: broadband noise at two levels (65 and 100 dBA) four 30 min. experimental sessions, different randomised orders
Threshold of acceptability	---
Effects of exposure duration	Trend of the data suggest that, for longer exposure durations, the drop in performance would have been significantly greater when vibration is present than it is not.
Conditions : lab, field study (aviation or other)	Lab (electro-dynamic shaker)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	12 male Air Force military personnel members of the AMRL Vibration panel 23-40 years
Task/activities description : input details (display size, position), performance measures, training	<u>Human performance:</u> complex counting task (CCT): simultaneous count of the number of flashes of three lights; subject has to press each light`s button every sixth time it flashed; two practice sessions à 30 min.
Comments	100 dBA noise and the combination of 65 dBA noise and vibration produce significantly poorer performance than 65 dBA noise alone or combined 100 dBA noise and vibration.

References: Harris, C.S. & Shoenberger, R.W. Combined effects of broadband noise and complex waveform vibration on cognitive performance. Aviation, Space and Environmental Medicine, 51, 1980, pp. 1-5.

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Other ref.

23

- Frequency : Medium
- Axis : x
- Task or measure : communication

24

- Frequency : Medium
- Axis : y
- Task or measure : communication

25

- Frequency : Medium
- Axis : z
- Task or measure : communication

Effects of vertical medium frequency vibration on tracking

Ref. 1.3

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 5 Hz Sinusoidal Axis : z 0.30 Peak G Input: by a chair attached to vibration table Duration : 35 min
Threshold of acceptability	
Effects of exposure duration	Exposure to vibration causes a marked impairment of visual acuity and tracking ability.
Conditions : lab, field study (aviation or other)	Lab for aviation study
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	10 male military personnel
Task or measure/activities description : input details (display size, position), performance measures, training	<u>Human performance</u> : Tracking ability, mental arythmetic, reaction time, visual acuity, voice comm. <u>Physiological measures</u> : body temperature, heart rate, weight loss, subjective ratings of the stress.
Comments	Combined-stress condition (heat, noise and vibrations) is less disturbing to the subjects and their performance than is vibration alone.

References: GRETHER (W.F.) et al.: Effects of combined heat, noise and vibration stress on human performance and physiological functions. In: Aerospace Medicine, 1971, October, pp. 1092-1097.

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Other ref.

Effects of vertical medium frequency vibration on speaking

Ref. 2.1

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 3.1 - 6.3 Hz Quasi random Axis : z 0.30 Peak G Input: by a chair attached to vibration table
Threshold of acceptability	Medium level of vib = well above the threshold of perception Medium level of vib = subjectively describes as unpleasant
Effects of exposure duration	Speech produced under vibration has un unmistakable, unusual quality. The most noticeable is voice tremolo
Conditions : lab, field study (aviation or other)	Lab for aviation study
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	4 young male military personnel, volunteer active duty Air Force personnel
Task or measure/activities description : input details (display size, position), performance measures, training	Reading 5 tokens of each words of a list of 15 words from the vocalulary that would be used to control a multi-functionnal display in a F-16 Aircraft.

Comments Modification of quality of speech under vertical medium vibration: increase of amplitude modulation and voice tremolo, about **15%** in comparison to the control condition (without vibration)

References: BOND (Z.S.) and MOORE (T.J.): Effects of whole-body vibration on acoustic measures of speech. In: Aviation, Space and Environmental Medicine, 1990, November, pp. 989-993.

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Other ref.

Effects of vertical medium frequency vibration on communication

Ref. 1.2

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 5 Hz Sinusoidal Axis : z 0.30 Peak G Input: by a chair attached to vibration table Duration : 35 min
Threshold of acceptability	
Effects of exposure duration	No effect on auditive perception performance (communication Task or measures).
Conditions : lab, field study (aviation or other)	Lab for aviation study
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	10 male military personnel
Task or measure/activities description : input details (display size, position), performance measures, training	Human performance : Tracking ability, mental arythmetic, reaction time, visual acuity, voice comm. Physiological measures : body temperature, heart rate, weight loss, subjective ratings of the stress.
Comments	Combined-stress condition (heat, noise and vibrations) is less disturbing to the subjects and their performance than is vibration alone.

References: GRETHER (W.F.) et al.: Effects of combined heat, noise and vibration stress on human performance and physiological functions. In: Aerospace Medicine, 1971, October, pp. 1092-1097.

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Other ref.

26

- Frequency : Medium
- Axis : x
- Task or measure : reading and data process

Effects of horizontal medium frequency vibration on reading

Ref. 3

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 0.5 - 10 Hz Random Axis : x and y Magnitude : 1.0 and 1.25 m/s^2 Input: by a chair with backrest attached to vibration table
Threshold of acceptability	
Effects of exposure duration	Horizontal vibration of seated subjects cause a maximum measured reduction in the speed of reading at 4 Hz, to a lesser extent at 3.15 Hz and 5 Hz.
Conditions : lab, field study (aviation or other)	Lab
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	16 subjects (8 male, 8 female), aged from 19 to 30 years
Task or measure/activities description : input details (display size, position), performance measures, training	Reading of 68 sheets of paper containing a photocopy of the first leader article in an edition of the london Times. Reading speed is calculated from the number of syllables read in a 30s period.
Comments	Horizontal medium frequency vibration have a more important effect on reading speed than lateral medium frequency vibration (probably because of transmission of vibrations by backrest seat).

References: GRIFFIN (M.J.); HAYWARD (R.A.): Effects of horizontal whole-body vibration on reading. In: Applied Ergonomics, 1994, Vol 25, n°3, pp. 165-169.

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Other ref.

Vibration Frequency, Axis, Seating Conditions and Reading Performance

Ref. 22

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: z-axis: 2.8-63 Hz Magnitude: 0.56-8.0 rms ms^{-2} y-axis: 2.8-31.5 Hz 0.40-8.0 rms ms^{-2} x-axis: 2.8-31.5 Hz 0.40-5.6 rms ms^{-2} all stimuli sinusoidal, frequencies spaced at half-octaves, five vibration magnitudes per frequency Axis : x,y, z Input: by a seat
Threshold of acceptability	six experiment. blocks with vibration stimuli+seating conditions: 1. rigid flat seat with backrest+attached foot rest (simulated helicopter seat), 2. rigid flat seat without backrest and with a stationary foot rest
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (electro-dynamic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	10 male subjects
Task/activities description : input details (display size, position), performance measures, training	Human performance: paced numeral reading from a CRT display, characters subtend 5 min arc at 0.75 m
Comments	With both seats the effect of vibration level on reading accuracy is significant at all but the highest frequencies of z-axis vibration. It is also significant for x-axis vibration with the helicopter seat, but not for x-axis vibration with the flat seat or for y-axis vibration with either seat. Equal performance contours indicate that z-axis vibration of the helicopter seat extends the effects of vibration to higher frequencies compared with the flat seat. Vibration in x-axis up to 5.6 Hz with the helicopter seat results in performance decrease of a similar level to those caused by the same magnitude of z-axis vibration.

References: Lewis, C.H. & Griffin, M.J. Predicting the effects of vibration frequency and axis and seating conditions on the reading of numeric displays. Ergonomics, 23, 1980b, pp. 485-501.

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Other ref.

27

- Frequency : Medium
- Axis : y
- Task or measure : reading and data process

Effects of horizontal medium frequency vibration on reading

Ref. 3

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 0.5 - 10 Hz Random Axis : x and y Magnitude : 1.0 and 1.25 m/s^2 Input: by a chair with backrest attached to vibration table
Threshold of acceptability	
Effects of exposure duration	Horizontal vibration of seated subjects cause a maximum measured reduction in the speed of reading at 4 Hz, to a lesser extent at 3.15 Hz and 5 Hz.
Conditions : lab, field study (aviation or other)	Lab
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	16 subjects (8 male, 8 female), aged from 19 to 30 years
Task or measure/activities description : input details (display size, position), performance measures, training	Reading of 68 sheets of paper containing a photocopy of the first leader article in an edition of the london Times. Reading speed is calculated from the number of syllables read in a 30s period.
Comments	Horizontal medium frequency vibration have a more important effect on reading speed than lateral medium frequency vibration (probably because of transmission of vibrations by backrest seat).

References: GRIFFIN (M.J.); HAYWARD (R.A.): Effects of horizontal whole-body vibration on reading. In: Applied Ergonomics, 1994, Vol 25, n°3, pp. 165-169.

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Other ref.

Vibration Frequency, Axis, Seating Conditions and Reading Performance

Ref. 22

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: z-axis: 2.8-63 Hz Magnitude: 0.56-8.0 rms ms^{-2} y-axis: 2.8-31.5 Hz 0.40-8.0 rms ms^{-2} x-axis: 2.8-31.5 Hz 0.40-5.6 rms ms^{-2} all stimuli sinusoidal, frequencies spaced at half-octaves, five vibration magnitudes per frequency Axis : x,y, z Input: by a seat
Threshold of acceptability	six experiment. blocks with vibration stimuli+seating conditions: 1. rigid flat seat with backrest+attached foot rest (simulated helicopter seat), 2. rigid flat seat without backrest and with a stationary foot rest
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (electro-dynamic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	10 male subjects
Task/activities description : input details (display size, position), performance measures, training	Human performance: paced numeral reading from a CRT display, characters subtend 5 min arc at 0.75 m
Comments	With both seats the effect of vibration level on reading accuracy is significant at all but the highest frequencies of z-axis vibration. It is also significant for x-axis vibration with the helicopter seat, but not for x-axis vibration with the flat seat or for y-axis vibration with either seat. Equal performance contours indicate that z-axis vibration of the helicopter seat extends the effects of vibration to higher frequencies compared with the flat seat. Vibration in x-axis up to 5.6 Hz with the helicopter seat results in performance decrease of a similar level to those caused by the same magnitude of z-axis vibration.

References: Lewis, C.H. & Griffin, M.J. Predicting the effects of vibration frequency and axis and seating conditions on the reading of numeric displays. Ergonomics, 23, 1980b, pp. 485-501.

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Other ref.

Long-Term Effects of Vibration on Complex Psychomotor Performance

Ref. 12

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 2, 5 Hz (acceleration power peak) Magnitude: 0, 0.12, 0.16 rms G Axis : z, y (random) Input: by a seat experiment. blocks.: two frequencies at three vibration levels (one control), duration per block: 6 h, counterbalanced order of blocks
Threshold of acceptability	---
Effects of exposure duration	Improved tracking performance across experimental blocks reflects an adjustment to vibration. Improved tracking performance during the second and near the end of 6 h of one block indicates the danger of extrapolating long-term performance data from short exposures.
Conditions : lab, field study (aviation or other)	Lab (electro-hydraulic vibration simulator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	12 cadets of the U.S. Air Force Advanced Reserve Officers Training Corps, having flight experience two independent experimental groups (N=6) for each frequency
Task/activities description : input details (display size, position), performance measures, training	<u>Human performance</u>: continuous tracking, visual reaction time (response to a series of red and green lights), and auditory reaction time (response to a change in the frequency of an auditory signal); performance measures are taken during the first 45 min. of each h of a 6-h block; three 2 h practice sessions before the main experiment
Comments	All vibration conditions lead to significant decline in tracking performance when compared with control conditions. Tracking performance on the horizontal axis is consistently better that that on the vertical axis. The 5 Hz spectrum is the most detrimental to tracking performance. Warning light performance is not affected by vibration. Auditory signal performance is not impaired at all: only one out of every 200 critical signal is not detected.

References: Holland, C.L. Performance effects of long-term random vertical vibration. Human Factors, 9, 1967, pp. 93-104.

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Other ref.

28

- Frequency : Medium
- Axis : z
- Task or measure : reading and data process

Vertical Character Separation and Display Legibility During Vibration Exposure

Ref. 28

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 3.15, 4, 5 Hz Magnitude: 1.6, 2.8 rms ms- Axis : z (sinusoidal) Input: by a chair
Threshold of acceptability	---
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (electro-hydraulic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	12 male subjects
Task/activities description : input details (display size, position), performance measures, training	Human performance: numeral reading of a CRT display (Characters subtended 5 min arc and 12 min arc at 0.75 m. Characters were formed from a 5x7 dot-matrix with vertical character seperations of 4, 15, 26, 37 and 48 pixels.)

Comments For characters subtending 5 min arc significantly greater errors occur with 4 pixels spacing than at each of the larger separations. With characters subtending 12 min arc a significantly greater number of errors occur with the closest spacing but only at the largest vibration magnitude. Characters subtending 12 min arc are likely to be found on displays in operational vibrating environments. Vertical character seperation in excess of 57.1% may be required to achieve maximum legibility.

References: Moseley, M.J. The effects of vibration on visual performance and display legibility. Ph.D. Thesis. 1986, University of Southampton.

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Other ref.

Comparison of Display, Whole-Body and Simultaneous Whole-Body-and-Display Vibration on Reading Performance

Ref. 27

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 0.5-5.0 Hz Magnitude: 1.0-2.5 rms ms^{-2} Axis : z (sinusoidal) Input: by a seat experimental conditions: 11 frequencies at 5 magnitudes (55 stimuli), three blocks: 1. display, 2. subject, 3. subject+display vibrating, randomised order
Threshold of acceptability	---
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (hydraulic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	15 male subjects all under 30 years
Task/activities description : input details (display size, position), performance measures, training	Human performance: numeral reading of a CRT display (characters subtend 5 min arc and 12 min arc at 0.75 m)

Comments For frequencies below 4 Hz display vibration produces the largest performance decrements and whole-body-and-display vibration the least. Whole-body vibration with a stationary display produces significantly worse performance than simultaneous vibration of both observer and display but significantly better performance than display vibration alone. The variations in performance with frequency and viewing condition are consitent across all vibration magnitudes.

References: Moseley, M.J. & Griffin, M.J. Effects of display vibration and whole-body vibration on visual performance. Ergonomics, 29, 1986, pp. 977-983.

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Other ref.

Effects of Sinusoidal and Random Whole-body Vibration on Reading Performance

Ref. 29

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: a) 2.5-31.5 Hz sinusoidal Magnitude: 1.8-4.0 rms ms^{-2} b) 2.5-31.5 Hz 1/3 octave band random, 1.8-4.0 rms ms^{-2} c) 4.0-16.0 Hz broad-band random, 2.0 rms ms^{-2} Axis : z Input: by a seat four blocks of vibration stimuli, randomised orders within each block, blocks balanced between subjects
Threshold of acceptability	---
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (electro-dynamic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	12 male subjects 19-35 years
Task/activities description : input details (display size, position), performance measures, training	Human performance: paced numeral reading task from a display: subjects are instructed to read aloud 50 numerals on a display whilst being paced at one character per second by a short tone burst; practice sessions with and without vibration present
Comments	Random vibration produces significantly less effect on reading performance than sinusoidal vibration of similar frequencies and R.M.S. acceleration levels. Measurements of rotational head motion show that this is due to differences in the eye velocity distributions produced by different motions. R.M.S. and R.M.Q. averaging procedures applied to broad-band vibrations are valid predictors of reading error when compared with error scores.

References: Moseley, M.J., Lewis, C.H. & Griffin, M.J. Sinusoidal and random whole-body vibration: comparative effects on visual performance. Aviation, Space and Environmental Medicine, 53, 1982, pp. 1000-1005.

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Other ref.

Effects of vertical medium frequency vibration on calculating

Ref. 5.1

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 5 Hz Sinusoidal Axis : z 0.25 Peak G Input: by a chair with a widden seat
Threshold of acceptability	
Effects of exposure duration	Significant reduction in the number of correct answers in calculating Task or measures when these vibrations are combined with high levels of noise (100 - 110 dB).
Conditions : lab, field study (aviation or other)	Lab
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	10 male military members of the US Air Force, volunteers, ranging from 23 to 30 years
Task or measure/activities description : input details (display size, position), performance measures, training	Human performance: - tracking Task or measures - complex reaction time with calculating
Comments	High level noise (100 - 110 dB) when combined with vibration produce more adverse effects than either of the stressors alone.

References: Harris, C.S. & Sommer, H.C. (1973). Interactive effects of intense noise and low-level vibration on tracking performance and response time. *Aerospace Medicine*, 44, 1013-1016.

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Other ref.

Effects of vertical medium frequency vibration on tracking

Ref. 1.3

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 5 Hz Sinusoidal Axis : z 0.30 Peak G Input: by a chair attached to vibration table Duration : 35 min
Threshold of acceptability	
Effects of exposure duration	Exposure to vibration causes a marked impairment of visual acuity and tracking ability.
Conditions : lab, field study (aviation or other)	Lab for aviation study
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	10 male military personnel
Task or measure/activities description : input details (display size, position), performance measures, training	Human performance : Tracking ability, mental arythmetic, reaction time, visual acuity, voice comm. Physiological measures : body temperature, heart rate, weight loss, subjective ratings of the stress.
Comments	Combined-stress condition (heat, noise and vibrations) is less disturbing to the subjects and their performance than is vibration alone.

References: GRETHER (W.F.) et al.: Effects of combined heat, noise and vibration stress on human performance and physiological functions. In: Aerospace Medicine, 1971, October, pp. 1092-1097.

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Other ref.

Ref. 12

Long-Term Effects of Vibration on Complex Psychomotor Performance

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 2, 5 Hz (acceleration power peak) Magnitude: 0, 0.12, 0.16 rms G Axis : z, y (random) Input: by a seat experiment. blocks.: two frequencies at three vibration levels (one control), duration per block: 6 h, counterbalanced order of blocks
Threshold of acceptability	---
Effects of exposure duration	Improved tracking performance across experimental blocks reflects an adjustment to vibration. Improved tracking performance during the second and near the end of 6 h of one block indicates the danger of extrapolating long-term performance data from short exposures.
Conditions : lab, field study (aviation or other)	Lab (electro-hydraulic vibration simulator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	12 cadets of the U.S. Air Force Advanced Reserve Officers Training Corps, having flight experience two independent experimental groups (N=6) for each frequency
Task/activities description : input details (display size, position), performance measures, training	Human performance: continuous tracking, visual reaction time (response to a series of red and green lights), and auditory reaction time (response to a change in the frequency of an auditory signal); performance measures are taken during the first 45 min. of each h of a 6-h block; three 2 h practice sessions before the main experiment
Comments	All vibration conditions lead to significant decline in tracking performance when compared with control conditions. Tracking performance on the horizontal axis is consistently better that that on the vertical axis. The 5 Hz spectrum is the most detrimental to tracking performance. Warning light performance is not affected by vibration. Auditory signal performance is not impaired at all: only one out of every 200 critical signal is not detected.

References:

Holland, C.L. Performance effects of long-term random vertical vibration. Human Factors, 9, 1967, pp. 93-104.

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Other ref.

Effects of Vibration on Complex Psychomotor Performance

Ref. 33

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 5 Hz Magnitude: 0.20-0.30 G 7 Hz 0.25-0.35 G 11 Hz 0.30-0.60 G Axis : z (sinusoidal) Input: by a seat three experiments for each frequency at four vibration levels (4 runs à 30 min, counterbalanced order)
Threshold of acceptability	
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (electro-magnetic shaker)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	23 male Air Force personnel three independent groups for each frequency
Task/activities description : input details (display size, position), performance measures, training	Human performance: simultaneous target identification, probability monitoring, and warning-lights monitoring; six 1 h practice sessions before the main experiment
Comments	There is very little evidence of vibration induced performance decrements. Vibration conditions produce significant effects in probability monitoring response time at 5 Hz (highest vibration level < control, medium level) and in green warning-lights response at 7 Hz (highest and medium level > control) and 11 Hz (highest level > lowest level). Direct mechanical interference with the motor aspects of the task is the most significant factor contributing to performance decrements.

References: Shoenberger, R.W. Effects of vibration on complex psychomotor performance. Aerospace Medicine, 38, 1967, pp. 1264-1269.

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Other ref.

Ref. 5

Effects of Combined Noise, Vibration and Heat on Physiological, Biochemical, Cognitive, and Subjective Parameters

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 5 Hz; Magnitude: 0.30 G (peak) Axis : z (sinusoidal); Input: by a chair other stressors: heat (22, 48 º C), noise (80, 105 dB) four experiment. combinations à 95 min.: 1. control, 2. vibration only, 3. vibration+heat, 4. vibration+ heat+noise
Threshold of acceptability	---
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (mechanical vibration table)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	12 male military personnel six of the 12 participated in an earlier experiment, 6 are new experienced subjects: 2 hours of retraining on performance tests; new subjetcs: 4 hours of training
Task/activities description : input details (display size, position), performance measures, training	Physiological measures: skin and rectal temperature, heart rate, weight loss, urine (collected for 24 hours), accelerometer Human performance: tracking, choice reaction time, communication test of logical alternatives, mental arithmetic, visual acuity Subjective ratings: stress severity scale, semantic differential regarding severity and intrusiveness of the stress conditions
Comments	There are significant effects for skin and rectal temperatures, heart rate and weight loss probably caused by heat. However, effects due to heat cannot be isolated since there was no single heat condition. On tracking and reaction time tests the greatest impairment of performance is producred by single vibration. The combination of all stressors produces antagonistic rather than additive performance effects. Accelerometer measures indicate that transmissibility of vibration is not altered by heat or noise. Subjective ratings of stress severity progressively increase with the number of stressors; ratings of intrusiveness does not show such a trend.

References:

Grether, W.F. et al. Further study on combined heat, noise and vibration stress. Aerospace Medicine, 43, 1972, pp. 641-645.

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Other ref.

Effects of Broadband Noise and Complex Waveform Vibration on Cognitive Performance

Ref. 10

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 2.6, 4.1, 6.3, 10, 16 Hz Magnitude: 0.36 rms G quasi-random sum-of-sines vibrations Axis : z Input: by a seat other stressor: broadband noise at two levels (65 and 100 dBA) four 30 min. experimental sessions, different randomised orders
Threshold of acceptability	---
Effects of exposure duration	Trend of the data suggest that, for longer exposure durations, the drop in performance would have been significantly greater when vibration is present than it is not.
Conditions : lab, field study (aviation or other)	Lab (electro-dynamic shaker)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	12 male Air Force military personnel members of the AMRL Vibration panel 23-40 years
Task/activities description : input details (display size, position), performance measures, training	<u>Human performance:</u> complex counting task (CCT): simultaneous count of the number of flashes of three lights; subject has to press each light`s button every sixth time it flashed; two practice sessions à 30 min.
Comments	100 dBA noise and the combination of 65 dBA noise and vibration produce significantly poorer performance than 65 dBA noise alone or combined 100 dBA noise and vibration.

References: Harris, C.S. & Shoenberger, R.W. Combined effects of broadband noise and complex waveform vibration on cognitive performance. Aviation, Space and Environmental Medicine, 51, 1980, pp. 1-5.

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Other ref.

Display Legibility During Whole-Body Vibration Exposure

Ref. 20

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 4.0 Hz, 11.2 Hz Magnitude: 0.4-2.0 rms ms^{-2}, 0.56-2.8 rms ms^{-2} Axis : z (sinusoidal) Input: by a seat
Threshold of acceptability	---
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (electro-hydraulic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	10 male subjects
Task/activities description : input details (display size, position), performance measures, training	Human performance: paced numeral reading from a CRT display (Characters subtend 4.58, 5.73, 7.56, 9.17 min arc at a constant viewing distance of 0.75 m)
Comments	Significant linear trends are present in the increasing reading errors with vibration magnitude at both frequencies at all except the larget character size (9.17 min arc). Data indicate that characters subtending an angular height of approximately 10 min arc could be only read with acceptable levels of error (about 8%) at vibration magnitudes less than 0.4 rms ms^{-2}. The size of characters should be increased by 50% for every doubling of the weighted z-axis vibration level.

References: Lewis, C.H. & Griffin, M.J. The effect of the character size on the legibility of numeric displays during vertical whole-body vibration. Journal of Sound and Vibration, 76, 1979b, pp. 562-565.

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Other ref.

Comparison of Display, Whole-Body and Simultaneous Whole-Body-and-Display Vibration on Reading Performance

Ref. 27

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 0.5-5.0 Hz; Magnitude: 1.0-2.5 rms ms^{-2} Axis : z (sinusoidal); Input: by a seat experimental conditions: 11 frequencies at 5 magnitudes (55 stimuli), three blocks: 1. display, 2. subject, 3. subject+display vibrating, randomised order
Threshold of acceptability	---
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (hydraulic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	15 male subjects all under 30 years
Task/activities description : input details (display size, position), performance measures, training	Human performance: numeral reading of a CRT display (characters subtend 5 min arc and 12 min arc at 0.75 m)

Comments For frequencies below 4 Hz display vibration produces the largest performance decrements and whole-body-and-display vibration the least. Whole-body vibration with a stationary display produces significantly worse performance than simultaneous vibration of both observer and display but significantly better performance than display vibration alone. The variations in performance with frequency and viewing condition are consitent across all vibration magnitudes.

References:

Moseley, M.J. & Griffin, M.J. Effects of display vibration and whole-body vibration on visual performance. Ergonomics, 29, 1986, pp. 977-983.

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Other ref.

Vibration Frequency, Axis, Seating Conditions and Reading Performance

Ref. 22

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: z-axis: 2.8-63 Hz Magnitude: 0.56-8.0 rms ms^{-2} y-axis: 2.8-31.5 Hz 0.40-8.0 rms ms^{-2} x-axis: 2.8-31.5 Hz 0.40-5.6 rms ms^{-2} all stimuli sinusoidal, frequencies spaced at half-octaves, five vibration magnitudes per frequency Axis : x,y, z Input: by a seat
Threshold of acceptability	six experiment. blocks with vibration stimuli+seating conditions: 1. rigid flat seat with backrest+attached foot rest (simulated helicopter seat), 2. rigid flat seat without backrest and with a stationary foot rest
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (electro-dynamic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	10 male subjects
Task/activities description : input details (display size, position), performance measures, training	Human performance: paced numeral reading from a CRT display, characters subtend 5 min arc at 0.75 m
Comments	With both seats the effect of vibration level on reading accuracy is significant at all but the highest frequencies of z-axis vibration. It is also significant for x-axis vibration with the helicopter seat, but not for x-axis vibration with the flat seat or for y-axis vibration with either seat. Equal performance contours indicate that z-axis vibration of the helicopter seat extends the effects of vibration to higher frequencies compared with the flat seat. Vibration in x-axis up to 5.6 Hz with the helicopter seat results in performance decrease of a similar level to those caused by the same magnitude of z-axis vibration.

References: Lewis, C.H. & Griffin, M.J. Predicting the effects of vibration frequency and axis and seating conditions on the reading of numeric displays. Ergonomics, 23, 1980b, pp. 485-501.

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Other ref.

29

- Frequency : Medium
- Axis : x
- Task or measure : well being, fatigue, alertness

Physiological Effects of Combined Noise and Vibration Stressors on Wakefulness during Flight

Ref. 14

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 1-80 Hz Magnitude: 0.09-0.90 m/s^2 Axis : x,y, z Input: by a chair (highest vibration levels below 50 Hz in z-axis) Helicopter types: Hkp 3, Hkp 6 Long-distance flights: 4 h, short distance flights: 2 h
Threshold of acceptability	---
Effects of exposure duration	Monotonous low frequency vibrations induce fatigue. Fatigue is pronounced during long-term flights compared to short term-flights
Conditions : lab, field study (aviation or other)	Aviation
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	12 pilots aged from 28-41 aviators in the infantry of AF1 Boden with more than 1000 flight hours
Task/activities description : input details (display size, position), performance measures, training	Physiological measures: EEG and ECG recordings
Comments	The level of wakefulness depends on stress/workload upon the pilot: take-offs, landings, unexpected events are correlated with an increased level of wakefulness. The monotony of flying route reduces wakefulness. There is no correlation between wakefulness/fatigue and type of flying.

References: Landström, U. & Löfstedt, M. Noise, vibration and changes in wakefulness during helicopter flight. Aviation, Space and Environmental Medicine, 58, 1987, pp. 109-118.

Return to main table

Other ref.

30

- Frequency : Medium
- Axis : y
- Task or measure : well being, fatigue, alertness

Physiological Effects of Combined Noise and Vibration Stressors on Wakefulness during Flight

Ref. 14

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 1-80 Hz Magnitude: 0.09-0.90 m/s^2 Axis : x,y, z Input: by a chair (highest vibration levels below 50 Hz in z-axis) Helicopter types: Hkp 3, Hkp 6 Long-distance flights: 4 h, short distance flights: 2 h
Threshold of acceptability	---
Effects of exposure duration	Monotonous low frequency vibrations induce fatigue. Fatigue is pronounced during long-term flights compared to short term-flights
Conditions : lab, field study (aviation or other)	Aviation
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	12 pilots aged from 28-41 aviators in the infantry of AF1 Boden with more than 1000 flight hours
Task/activities description : input details (display size, position), performance measures, training	Physiological measures: EEG and ECG recordings
Comments	The level of wakefulness depends on stress/workload upon the pilot: take-offs, landings, unexpected events are correlated with an increased level of wakefulness. The monotony of flying route reduces wakefulness. There is no correlation between wakefulness/fatigue and type of flying.

References: Landström, U. & Löfstedt, M. Noise, vibration and changes in wakefulness during helicopter flight. Aviation, Space and Environmental Medicine, 58, 1987, pp. 109-118.

Return to main table

Other ref.

31

- Frequency : Medium
- Axis : z
- Task or measure : well being, fatigue, alertness

Physiological Effects of Combined Noise and Vibration Stressors on Wakefulness during Flight

Ref. 14

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 1-80 Hz Magnitude: 0.09-0.90 m/s^2 Axis : x,y, z Input: by a chair (highest vibration levels below 50 Hz in z-axis) Helicopter types: Hkp 3, Hkp 6 Long-distance flights: 4 h, short distance flights: 2 h
Threshold of acceptability	---
Effects of exposure duration	Monotonous low frequency vibrations induce fatigue. Fatigue is pronounced during long-term flights compared to short term-flights
Conditions : lab, field study (aviation or other)	Aviation
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	12 pilots aged from 28-41 aviators in the infantry of AF1 Boden with more than 1000 flight hours
Task/activities description : input details (display size, position), performance measures, training	<u>Physiological measures:</u> EEG and ECG recordings
Comments	The level of wakefulness depends on stress/workload upon the pilot: take-offs, landings, unexpected events are correlated with an increased level of wakefulness. The monotony of flying route reduces wakefulness. There is no correlation between wakefulness/fatigue and type of flying.

References: Landström, U. & Löfstedt, M. Noise, vibration and changes in wakefulness during helicopter flight. Aviation, Space and Environmental Medicine, 58, 1987, pp. 109-118.

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Other ref.

Combined Effects of Noise and Whole-Body Vibration on Wakefulness, Subjective Ratings and Performance

Ref. 16

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 1-63 Hz Magnitude: 0.3 ms^{-2} Axis : z Input: by a seat three consecutive exposure conditions à 30 min: 1. noise, 2. vibration, 3. noise+vibration, balanced order
Threshold of acceptability	---
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (electro-dynamic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	24 subjects (12 males and 12 females) 19-35 years
Task/activities description : input details (display size, position), performance measures, training	Physiological measures: EEG recordings, pulse rate Human performance: reaction time Subjective ratings: drowsiness, annoyance
Comments	Combined exposure of vibration with 71 dBA noise is associated with the highest fatigue as judged from the physiological variables and subjective ratings. Combined exposure yields the highest mean annoyance, pulse rate and longest reaction times. Differences between exposure conditions are very small and non significant.

References: Landström, U., Kjellberg, A. & Lundström, R. Combined effects of exposure to noise and whole-body vibrations in dumpers, helicopters and railway engines. Journal of Low Frequency Noise and Vibration, 12, 1993, pp.75-85.

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Other ref.

Ref. 5

Effects of Combined Noise, Vibration and Heat on Physiological, Biochemical, Cognitive, and Subjective Parameters

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 5 Hz Magnitude: 0.30 G (peak) Axis : z (sinusoidal) Input: by a chair other stressors: heat (22, 48 º C), noise (80, 105 dB) four experiment. combinations à 95 min.: 1. control, 2. vibration only, 3. vibration+heat, 4. vibration+ heat+noise
Threshold of acceptability	---
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (mechanical vibration table)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	12 male military personnel six of the 12 participated in an earlier experiment, 6 are new experienced subjects: 2 hours of retraining on performance tests; new subjetcs: 4 hours of training
Task/activities description : input details (display size, position), performance measures, training	Physiological measures: skin and rectal temperature, heart rate, weight loss, urine (collected for 24 hours), accelerometer Human performance: tracking, choice reaction time, communication test of logical alternatives, mental arithmetic, visual acuity Subjective ratings: stress severity scale, semantic differential regarding severity and intrusiveness of the stress conditions
Comments	There are significant effects for skin and rectal temperatures, heart rate and weight loss probably caused by heat. However, effects due to heat cannot be isolated since there was no single heat condition. On tracking and reaction time tests the greatest impairment of performance is producred by single vibration. The combination of all stressors produces antagonistic rather than additive performance effects. Accelerometer measures indicate that transmissibility of vibration is not altered by heat or noise. Subjective ratings of stress severity progressively increase with the number of stressors; ratings of intrusiveness does not show such a trend.

References:

Grether, W.F. et al. Further study on combined heat, noise and vibration stress. Aerospace Medicine, 43, 1972, pp. 641-645.

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Other ref.

Effects of Whole-Body Vibration on Changes in Wakefulness During Flight

Ref. 15

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 3 Hz sinusoidal; 2-20 Hz broad-band random Magnitude: 0.3 rms ms^{-2} Axis : z Input: by a seat seven experiment. blocks: four pauses, three stimulus exposures, each 15 min. (total duration 105 min.)
Threshold of acceptability	---
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (electro-dynamic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	20 subjects (10 males, 10 females): sinusoidal vibration 28 subjects (14 males, 14 females): random vibration 22-38 years
Task/activities description : input details (display size, position), performance measures, training	<u>Physiological measures:</u> EEG, EOG, and ECG recordings During the last 5 min. of each period the subject sits with closed eyes. Subjects are told to relax during the study.
Comments	Compared with pauses without exposure, exposure to whole-body vibration is found to be correlated with a reduction in wakefulness (increase of theta and decrease of alpha activity during periods of eye closure). This effect is greater during sinusoidal than random vibration which is explained in terms of decreased sensory stimulation.

References: Landström, U. & Lundström, R. Changes in wakefulness during exposure to whole body vibration. Electroencephal. Clin. Neurophysiology, 61, 1985, pp. 411-415.

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Other ref.

32

- Frequency : High
- Axis : x
- Task or measure : tracking

33

- Frequency : High
- Axis : y
- Task or measure : tracking

34

- Frequency : High
- Axis : z
- Task or measure : tracking

Effects of vertical high frequency vibration on physiological functions

Ref. 6

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 18 Hz Magnitude : 2 - 5 m/s^2 Axis : z Similar to helicopter vib Input: by a chair or a moving walkway
Threshold of acceptability	
Effects of exposure duration	Postural stability, visiomotor pursuit and volunteer motor activities show a significant impairment during vib exposure. Effects persist after stimulations.
Conditions : lab, field study (aviation or other)	Lab for aviation study (helicopter)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	Helicopter pilots, seated or standing subjects
Task or measure/activities description : input details (display size, position), performance measures, training	- Postural stability, - Tracking, - volunteer motor activities
Comments	Selective vibrations applications on different body parts permit to locate input vibrations and suggest that muscular proprioceptive system is responsible for observed impairments.

References: GAUTHIER et al.: Les laboratoires français effectuant des études de vibrations en relation avec l'être humain: le Laboratoire de psychophysiologie de l'Univ. de Provence. In: Les vibrations industrielles. Doc INRS. Mars 1983. Pp 134-135.

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Other ref.

Influence of Low Frequency Vibration on Control and Navigation Performance

Ref. 37

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 6, 8, 10, 12 Hz Magnitude: 0.10-0.30 rms G Axis : z Input: by a seat experiment. blocks.: 12 days of data collection, pilots fly two 2 h missions each day under different vibration conditions in randomised order
Threshold of acceptability	---
Effects of exposure duration	Vibration conditions do not degrade performance for at least a 2 h period.
Conditions : lab, field study (aviation or other)	Lab (fixed-base helicopter simulator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	4 army pilots
Task/activities description : input details (display size, position), performance measures, training	Human performance: control/navigation task in the flight simulator (performance is measured in terms of deviations from desired flight path, altitude and airspeed values; times required to perform load pick-up and drop-off as well as load placement accuracy are also measured); 8 h practice before main experiment
Comments	Vibration stimuli do not degrade performance. Performance tends to improve with increased stress. This trend is due to motivation, i.e. as pilots feel the onset of fatigue they compensate by working harder. On about 6% of the scores pilots exhibit sudden short-term lapses (length of seconds) in their ability to respond to display indications independently of stressors. This results in poor scores in the midst of otherwies normal data. These lapses are probably related to so-called „pilot-error“ accidents.

References:

Stave, A.M. The influence of low frequency vibration on pilot performance (as measured in a fixed base simulator). Ergonomics, 22, 1979, pp. 823-835.

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Other ref.

Effects of Combined Noise and Vibration on Tracking Performance and Response Time

Ref. 11

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 6 Hz Magnitude: 0.10 G (peak) Axis : z Input: by a chair other stressor: white noise at two levels (65 and 110 dBA) four 80 min. experimental sessions, counterbalanced order
Threshold of acceptability	---
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (electro-magnetic shaker)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	12 male students 19-24 years
Task/activities description : input details (display size, position), performance measures, training	Human performance: tracking task, reaction time five practice sessions à 80 min.
Comments	There is an additive detremental effect of noise and vibration on tracking task performance. Comparison with previous data indicate that increasing the high-intensity noise level from 100 to 110 dBA changes the interaction with vibration from a subtractive to an additive effect. Vibration has a greater impact on the vertical part of the tracking task than on the horizontal.

References: Harris, C.S. & Sommer, H.C. Interactive effects of intense noise and low-level vibration on tracking performance and response time. Aerospace Medicine, 44, 1973, pp. 1013-1016.

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Other ref.

35

- Frequency : High
- Axis : x
- Task or measure : manipulating

36

- Frequency : High
- Axis : y
- Task or measure : manipulating

37

- Frequency : High
- Axis : z
- Task or measure : manipulating

38

- Frequency : High
- Axis : x
- Task or measure : communication

39

- Frequency : High
- Axis : y
- Task or measure : communication

40

- Frequency : High
- Axis : z
- Task or measure : communication

Effects of vertical high frequency vibration on speaking

Ref. 2.2

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 8.1 - 25.1 Hz Quasi random Axis : z 0.30 Peak G Input: by a chair attached to vibration table
Threshold of acceptability	High level of vib = approximatively one half the limit of voluntary tolerance
Effects of exposure duration	Speech produced under vibration has un unmistakable, unusual quality. The most noticeable is voice tremolo and fragmented vowels.
Conditions : lab, field study (aviation or other)	Lab for aviation study
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	4 young male military personnel, volunteer active duty Air Force personnel
Task or measure/activities description : input details (display size, position), performance measures, training	Reading 5 tokens of each words of a list of 15 words from the vocalulary that would be used to control a multi-functionnal display in a F-16 Aircraft.

Comments Modification of speech quality under vertical medium vibration: increase of amplitude modulation and voice tremolo, about **30%** in comparison to the control condition (without vibration)

References: BOND (Z.S.) and MOORE (T.J.): Effects of whole-body vibration on acoustic measures of speech. In: Aviation, Space and Environmental Medicine, 1990, November, pp. 989-993.

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Other ref.

41

- Frequency : High
- Axis : x
- Task or measure : reading and data process

Vibration Frequency, Axis, Seating Conditions and Reading Performance

Ref. 22

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: z-axis: 2.8-63 Hz Magnitude: 0.56-8.0 rms ms^{-2} y-axis: 2.8-31.5 Hz 0.40-8.0 rms ms^{-2} x-axis: 2.8-31.5 Hz 0.40-5.6 rms ms^{-2} all stimuli sinusoidal, frequencies spaced at half-octaves, five vibration magnitudes per frequency
Threshold of acceptability	Axis : x,y, z Input: by a seat six experiment. blocks with vibration stimuli+seating conditions: 1. rigid flat seat with backrest+attached foot rest (simulated helicopter seat), 2. rigid flat seat without backrest and with a stationary foot rest
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (electro-dynamic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	10 male subjects
Task/activities description : input details (display size, position), performance measures, training	<u>Human performance</u>: paced numeral reading from a CRT display, characters subtend 5 min arc at 0.75 m
Comments	With both seats the effect of vibration level on reading accuracy is significant at all but the highest frequencies of z-axis vibration. It is also significant for x-axis vibration with the helicopter seat, but not for x-axis vibration with the flat seat or for y-axis vibration with either seat. Equal performance contours indicate that z-axis vibration of the helicopter seat extends the effects of vibration to higher frequencies compared with the flat seat. Vibration in x-axis up to 5.6 Hz with the helicopter seat results in performance decrease of a similar level to those caused by the same magnitude of z-axis vibration.

References: Lewis, C.H. & Griffin, M.J. Predicting the effects of vibration frequency and axis and seating conditions on the reading of numeric displays. Ergonomics, 23, 1980b, pp. 485-501.

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Other ref.

42

- Frequency : High
- Axis : y
- Task or measure : reading and data process

Vibration Frequency, Axis, Seating Conditions and Reading Performance

Ref. 22

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: z-axis: 2.8-63 Hz Magnitude: 0.56-8.0 rms ms^{-2} y-axis: 2.8-31.5 Hz 0.40-8.0 rms ms^{-2} x-axis: 2.8-31.5 Hz 0.40-5.6 rms ms^{-2} all stimuli sinusoidal, frequencies spaced at half-octaves, five vibration magnitudes per frequency Axis : x,y, z Input: by a seat
Threshold of acceptability	six experiment. blocks with vibration stimuli+seating conditions: 1. rigid flat seat with backrest+attached foot rest (simulated helicopter seat), 2. rigid flat seat without backrest and with a stationary foot rest
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (electro-dynamic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	10 male subjects
Task/activities description : input details (display size, position), performance measures, training	<u>Human performance</u>: paced numeral reading from a CRT display, characters subtend 5 min arc at 0.75 m
Comments	With both seats the effect of vibration level on reading accuracy is significant at all but the highest frequencies of z-axis vibration. It is also significant for x-axis vibration with the helicopter seat, but not for x-axis vibration with the flat seat or for y-axis vibration with either seat. Equal performance contours indicate that z-axis vibration of the helicopter seat extends the effects of vibration to higher frequencies compared with the flat seat. Vibration in x-axis up to 5.6 Hz with the helicopter seat results in performance decrease of a similar level to those caused by the same magnitude of z-axis vibration.

References:

Lewis, C.H. & Griffin, M.J. Predicting the effects of vibration frequency and axis and seating conditions on the reading of numeric displays. Ergonomics, 23, 1980b, pp. 485-501.

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Other ref.

43

- Frequency : High
- Axis : z
- Task or measure : reading and data process

Effects of Sinusoidal and Random Whole-body Vibration on Reading Performance

Ref. 29

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: a) 2.5-31.5 Hz sinusoidal Magnitude: 1.8-4.0 rms ms^{-2} b) 2.5-31.5 Hz 1/3 octave band random, 1.8-4.0 rms ms^{-2} c) 4.0-16.0 Hz broad-band random, 2.0 rms ms^{-2} Axis : z Input: by a seat four blocks of vibration stimuli, randomised orders within each block, blocks balanced between subjects
Threshold of acceptability	---
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (electro-dynamic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	12 male subjects 19-35 years
Task/activities description : input details (display size, position), performance measures, training	<u>Human performance</u>: paced numeral reading task from a display: subjects are instructed to read aloud 50 numerals on a display whilst being paced at one character per second by a short tone burst; practice sessions with and without vibration present
Comments	Random vibration produces significantly less effect on reading performance than sinusoidal vibration of similar frequencies and R.M.S. acceleration levels. Measurements of rotational head motion show that this is due to differences in the eye velocity distributions produced by different motions. R.M.S. and R.M.Q. averaging procedures applied to broad-band vibrations are valid predictors of reading error when compared with error scores.

References: Moseley, M.J., Lewis, C.H. & Griffin, M.J. Sinusoidal and random whole-body vibration: comparative effects on visual performance. Aviation, Space and Environmental Medicine, 53, 1982, pp. 1000-1005.

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Other ref.

Information Processing During Whole-Body Vibration Exposure

Ref. 34

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 10 Hz Magnitude: 0, ± 0.5 G Axis : z Input: by a seat experiment. blocks.: all subjects experience 18 treatments formed by the combination of 2 vibration levels, 3 levels of memory load (1, 2, 4 letters), 3 levels of exposure time (7, 21, 35 min.); two 1-h exp. sessions
Threshold of acceptability	---
Effects of exposure duration	Even with an extended duration (up to 35 min.), vibration does not increases RT in the Sternberg task, when visual interference effects are removed by increasing the display size. Errors tend to increase as a function of time
Conditions : lab, field study (aviation or other)	Lab (electro-magnetic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	12 male military personnel
Task/activities description : input details (display size, position), performance measures, training	Human performance: memory reaction time task by using letters of the alphabet (Sternberg task); two 1 h practice sessions before main experiment
Comments	The effect of vibration intensity on RT is not significant. Memory load has a significant effect on performance, i.e. RT increases consitently as memory load increases for every combination of the other experimental variables. Performance of the Sternberg task paradigm is suspectible to mechanical interference with peripheral processes but it is essentially immune to any central processing effect from the general stress of vibration.

References: Shoenberger, R.W. An investigation of human information processing during whole-body vibration. Aerospace Medicine, 45, 1974, pp. 143-153.

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Other ref.

Vibration Frequency, Axis, Seating Conditions and Reading Performance

Ref. 22

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: z-axis: 2.8-63 Hz Magnitude: 0.56-8.0 rms ms^{-2} y-axis: 2.8-31.5 Hz 0.40-8.0 rms ms^{-2} x-axis: 2.8-31.5 Hz 0.40-5.6 rms ms^{-2} all stimuli sinusoidal, frequencies spaced at half-octaves, five vibration magnitudes per frequency
Threshold of acceptability	Axis : x,y, z Input: by a seat six experiment. blocks with vibration stimuli+seating conditions: 1. rigid flat seat with backrest+attached foot rest (simulated helicopter seat), 2. rigid flat seat without backrest and with a stationary foot rest
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (electro-dynamic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	10 male subjects
Task/activities description : input details (display size, position), performance measures, training	Human performance: paced numeral reading from a CRT display, characters subtend 5 min arc at 0.75 m
Comments	With both seats the effect of vibration level on reading accuracy is significant at all but the highest frequencies of z-axis vibration. It is also significant for x-axis vibration with the helicopter seat, but not for x-axis vibration with the flat seat or for y-axis vibration with either seat. Equal performance contours indicate that z-axis vibration of the helicopter seat extends the effects of vibration to higher frequencies compared with the flat seat. Vibration in x-axis up to 5.6 Hz with the helicopter seat results in performance decrease of a similar level to those caused by the same magnitude of z-axis vibration.

References:

Lewis, C.H. & Griffin, M.J. Predicting the effects of vibration frequency and axis and seating conditions on the reading of numeric displays. Ergonomics, 23, 1980b, pp. 485-501.

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Other ref.

Effects of Vibration on Complex Psychomotor Performance

Ref. 33

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 5 Hz, Magnitude: 0.20-0.30 G 7 Hz, 0.25-0.35 G 11 Hz, 0.30-0.60 G Axis : z (sinusoidal) Input: by a seat three experiments for each frequency at four vibration levels (4 runs à 30 min, counterbalanced order)
Threshold of acceptability	
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (electro-magnetic shaker)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	23 male Air Force personnel three independent groups for each frequency
Task/activities description : input details (display size, position), performance measures, training	Human performance: simultaneous target identification, probability monitoring, and warning-lights monitoring; six 1 h practice sessions before the main experiment
Comments	There is very little evidence of vibration induced performance decrements. Vibration conditions produce significant effects in probability monitoring response time at 5 Hz (highest vibration level < control, medium level) and in green warning-lights response at 7 Hz (highest and medium level > control) and 11 Hz (highest level > lowest level). Direct mechanical interference with the motor aspects of the task is the most significant factor contributing to performance decrements.

References: Shoenberger, R.W. Effects of vibration on complex psychomotor performance. Aerospace Medicine, 38, 1967, pp. 1264-1269.

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Other ref.

44

- Frequency : High
- Axis : x
- Task or measure : well being, fatigue, alertness

Physiological Effects of Combined Noise and Vibration Stressors on Wakefulness during Flight

Ref. 14

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 1-80 Hz Magnitude: 0.09-0.90 m/s^2 Axis : x,y, z Input: by a chair (highest vibration levels below 50 Hz in z-axis) Helicopter types: Hkp 3, Hkp 6 Long-distance flights: 4 h, short distance flights: 2 h
Threshold of acceptability	---
Effects of exposure duration	Monotonous low frequency vibrations induce fatigue. Fatigue is pronounced during long-term flights compared to short term-flights
Conditions : lab, field study (aviation or other)	Aviation
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	12 pilots aged from 28-41 aviators in the infantry of AF1 Boden with more than 1000 flight hours
Task/activities description : input details (display size, position), performance measures, training	Physiological measures: EEG and ECG recordings
Comments	The level of wakefulness depends on stress/workload upon the pilot: take-offs, landings, unexpected events are correlated with an increased level of wakefulness. The monotony of flying route reduces wakefulness. There is no correlation between wakefulness/fatigue and type of flying.

References: Landström, U. & Löfstedt, M. Noise, vibration and changes in wakefulness during helicopter flight. Aviation, Space and Environmental Medicine, 58, 1987, pp. 109-118.

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Other ref.

45

- Frequency : High
- Axis : y
- Task or measure : well being, fatigue, alertness

Physiological Effects of Combined Noise and Vibration Stressors on Wakefulness during Flight

Ref. 14

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 1-80 Hz Magnitude: 0.09-0.90 m/s^2 Axis : x,y, z Input: by a chair (highest vibration levels below 50 Hz in z-axis) Helicopter types: Hkp 3, Hkp 6 Long-distance flights: 4 h, short distance flights: 2 h
Threshold of acceptability	---
Effects of exposure duration	Monotonous low frequency vibrations induce fatigue. Fatigue is pronounced during long-term flights compared to short term-flights
Conditions : lab, field study (aviation or other)	Aviation
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	12 pilots aged from 28-41 aviators in the infantry of AF1 Boden with more than 1000 flight hours
Task/activities description : input details (display size, position), performance measures, training	Physiological measures: EEG and ECG recordings
Comments	The level of wakefulness depends on stress/workload upon the pilot: take-offs, landings, unexpected events are correlated with an increased level of wakefulness. The monotony of flying route reduces wakefulness. There is no correlation between wakefulness/fatigue and type of flying.

References: Landström, U. & Löfstedt, M. Noise, vibration and changes in wakefulness during helicopter flight. Aviation, Space and Environmental Medicine, 58, 1987, pp. 109-118.

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Other ref.

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- Frequency : High
- Axis : z
- Task or measure : well being, fatigue, alertness

Effects of vertical high frequency vibration on physiological functions

Ref. 6

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 18 Hz Magnitude : 2 - 5 m/s^2 Axis : z Similar to helicopter vib Input: by a chair or a moving walkway
Threshold of acceptability	
Effects of exposure duration	Postural stability, visiomotor pursuit and volunteer motor activities show a significant impairment during vib exposure. Effects persist after stimulations.
Conditions : lab, field study (aviation or other)	Lab for aviation study (helicopter)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	Helicopter pilots, seated or standing subjects
Task or measure/activities description : input details (display size, position), performance measures, training	- Postural stability, - Tracking, - volunteer motor activities
Comments	Selective vibrations applications on different body parts permit to locate input vibrations and suggest that muscular proprioceptive system is responsible for observed impairments.

References: GAUTHIER et al.: Les laboratoires français effectuant des études de vibrations en relation avec l'être humain: le Laboratoire de psychophysiologie de l'Univ. de Provence. In: Les vibrations industrielles. Doc INRS. Mars 1983. Pp 134-135.

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Other ref.

Long-Term Control and Navigation Performance

Ref. 36

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 12, 17 Hz Magnitude: 0.10-0.40 G Axis : z (sinusoidal) Input: by a seat other stressors: noise (90, 95, 100 dB), time (3, 4 ,6 ,8 h)
Threshold of acceptability	---
Effects of exposure duration	Perception of fatigue is influenced by the lenght of time a subject has left in the simulator. Despite the onset of fatigue, performance improves with time.
Conditions : lab, field study (aviation or other)	Lab (fixed-base helicopter simulator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	5 helicopter pilots more than 1000 flight hours
Task/activities description : input details (display size, position), performance measures, training	Human performance: control/navigation task in the flight simulator (IFR route within the New York metropolitan area; performance is measured in terms of deviations from desired flight path and altitude values)
Comments	Vibration stimuli do not degrade performance. Performance actually improves with time. This is probably due to the increased éffort of the pilots to compensate fatigue. However, subjects does suffer from lapses resulting in very poor performance. These lapses are of short duration (seconds) and occur at unpredictable times. They are caused by a gap in attention. If several lapses occur during a short period of time, they could explain so-called „pilot-error“ accidents in actual flight.

References: Stave, A.M. The effects of cockpit environment on long-term pilot performance. Human Factors, 19, 1977, pp. 503-514.

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Other ref.

Physiological Effects of Combined Noise and Vibration Stressors on Wakefulness during Flight

Ref. 14

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 1-80 Hz Magnitude: 0.09-0.90 m/s^2 Axis : x,y, z Input: by a chair (highest vibration levels below 50 Hz in z-axis) Helicopter types: Hkp 3, Hkp 6 Long-distance flights: 4 h, short distance flights: 2 h
Threshold of acceptability	---
Effects of exposure duration	Monotonous low frequency vibrations induce fatigue. Fatigue is pronounced during long-term flights compared to short term-flights
Conditions : lab, field study (aviation or other)	Aviation
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	12 pilots aged from 28-41 aviators in the infantry of AF1 Boden with more than 1000 flight hours
Task/activities description : input details (display size, position), performance measures, training	<u>Physiological measures:</u> EEG and ECG recordings
Comments	The level of wakefulness depends on stress/workload upon the pilot: take-offs, landings, unexpected events are correlated with an increased level of wakefulness. The monotony of flying route reduces wakefulness. There is no correlation between wakefulness/fatigue and type of flying.

References: Landström, U. & Löfstedt, M. Noise, vibration and changes in wakefulness during helicopter flight. Aviation, Space and Environmental Medicine, 58, 1987, pp. 109-118.

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Other ref.

Combined Effects of Noise and Whole-Body Vibration on Wakefulness, Subjective Ratings and Performance

Ref. 16

Physical description of the stressor (frequency, direction, magnitude, duration, regularity, crest)	Frequency: 1-63 Hz Magnitude: $0.3\ ms^{-2}$ Axis : z Input: by a seat three consecutive exposure conditions à 30 min: 1. noise, 2. vibration, 3. noise+vibration, balanced order
Threshold of acceptability	---
Effects of exposure duration	---
Conditions : lab, field study (aviation or other)	Lab (electro-dynamic vibrator)
Sample sizes and characterization : type (pilot or other), experience, gender, age, body measures	24 subjects (12 males and 12 females) 19-35 years
Task/activities description : input details (display size, position), performance measures, training	<u>Physiological measures</u>: EEG recordings, pulse rate <u>Human performance:</u> reaction time <u>Subjective ratings:</u> drowsiness, annoyance
Comments	Combined exposure of vibration with 71 dBA noise is associated with the highest fatigue as judged from the physiological variables and subjective ratings. Combined exposure yields the highest mean annoyance, pulse rate and longest reaction times. Differences between exposure conditions are very small and non significant.

References:

Landström, U., Kjellberg, A. & Lundström, R. Combined effects of exposure to noise and whole-body vibrations in dumpers, helicopters and railway engines. Journal of Low Frequency Noise and Vibration, 12, 1993, pp.75-85.

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Other ref.