International Journal of Industrial Ergonomics 42 (2012) 513–524

Contents lists available at SciVerse ScienceDirect

International Journal of Industrial Ergonomics

journal homepage: www.elsevier.com/locate/ergon

Investigation of activity performance on laptop in vibration environment

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ARTICLE INFO

Article history:
Received 18 March 2011
Received in revised form
5 January 2012
Accepted 13 August 2012
Available online 19 September 2012

Keywords:
Pointing activity
Mouse clicking
Whole-body vibration
Fitts' law
Task performance
Activity comfort

ABSTRACT

The present study investigated effects of vibration direction, vibration magnitude, object size, object distance and angle of approach on movement time taken by eleven participants using a mouse to perform 'pointing and clicking' activity on a laptop. From the combination of vibration directions, vibration magnitudes, object sizes, object distances and angles of approach, a total of 416 exposure conditions were considered. For successful completion of 'pointing and clicking' activity under different exposure conditions, the time required to finish the task was measured. Using the Fitts' law, a relation between movement time and index of difficulty was developed for different vibration directions and magnitudes considered in the study. Higher vibration magnitudes, smaller size of the objects, and diagonal angular movements were found to affect the movement time and hence showed difficulties to perform the activity.

Relevance to industry: This study investigated the performance of a mouse to execute pointing and clicking activity on a laptop in vibration environment. The results showed that difficulties to perform the activity were due to higher magnitudes, smaller size of the objects, and diagonal cursor movements. These research achievements can help human–computer interaction design in various dynamic environments such as in land and sea vehicles.

1. Introduction

Many train passengers during travel experience difficulty in manipulating the mouse while working on laptop computers. Whole-body vibration (WBV) to which they are exposed onboard, affects human–computer interface (HCI) and degrade their performance (Griffin, 1990; Suzuki, 1998). An understanding of speed and accuracy of human motor movements associated with the computer input devices is important for better design of HCI and implementation of effective interface systems. Computer use is primarily dominated by pointing and clicking activities and touch screen, track ball and mouse are the most commonly used devices for performing these activities. Both pointing and clicking activities require precise hand movements which can be severely affected by vibration. Many models based on the Fitts' law are available to explain the relationship between speed and accuracy of human motor movements associated with computer devices. The key factors that influence movement time considered in these models include size of object, its distance from origin, angle of approach for a mouse to point and click an icon like target/object (Balakrishnan, 2005; Grossman and Balakrishnan, 2005; Whisenand and Emurian, 1995, 1996; 1999). However, all these models have been developed for static (no vibration) environment, and are inappropriate for vibration environments as in running trains/vehicles. Later, Liu et al. (2007) and Lin et al. (2010) analyzed suitability of pointing devices such as touch screen, mouse, and a track ball for vibration environment and found that mouse performed well than other devices. Further, Mansfield et al. (2007) demonstrated that mouse is better than touchpad under vibrating environments for pointing and clicking. Besides, the present ride comfort standards too, provide inadequate guidance on the effect of vibration on human performance during computer work. The effective interface between portable computer systems and human is necessary to ensure a comfortable working environment in moving vehicles. Developing an interface system to perform pointing and clicking task on moving vehicles requires thorough investigation of the interactive effects of vibration directions, magnitudes, object size, object distance and approaching angle to a displayed object/icon on hand movement. As the Fitts' law is used to express the difficulty to perform hand movement in terms of movement time and used to evaluate input devices in HCI field (Lin et al., 2010), the investigation should consider those interactive effects on movement time taken by a mouse to select icon like objects displayed on a laptop monitor. Therefore, the present study investigates the effects of

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http://dx.doi.org/10.1016/j.ergon.2012.08.005

vibration directions and its magnitudes on an indicator of difficulty such as movement time taken by the mouse while performing the task (pointing and clicking activity by a mouse) for different angles of approach, object sizes and distances.

1.1. Convention of vibration axes

WBV occurs when a human is supported by a surface that is shaking and the vibration affects the body parts remote from the site of exposure (Mansfield, 2005). For an example as in case of railway passengers, their body is supported at floor (by foot) at seat (by buttocks) at back rest (by back) and at headrest (by head). The vibration at these points is then transmitted through body from the supporting part of the body to the head through the nervous system, the skeleton, including the spine and ultimately the skull, which might have its own dynamic responses to the transmitted vibration (Mansfield, 2005). Degraded comfort, interference with activities, impaired health, perception of 'low' magnitude vibration and the occurrence of motion sickness are the effects of human response to WBV. For WBV measurements as per ISO 2631-1, 1997, the *X*-axis is defined in fore-and-aft direction, *Y*-axis in lateral direction and *Z*-axis in vertical directions as shown in Fig. 1.

1.2. Human activities under vibration

Pointing and clicking on a laptop monitor involves the transfer of information from the eye to brain for processing. The results of processed information are executed by transferring the information from the brain to hands. During the WBV, there is a higher probability that different parts of the human body will receive different vibrations which may alter the exposed person's conception of either the importance of activity (task) or the performance criteria which should be targeted (Griffin, 1990). Thus chances of modification in information at eye (input end of information), the hands (output end) and performance of input devices (monitor/display unit) and output devices (mouse) used to perform the activity (task) may occur which leads to impaired visual acuity and manual control (Lewis and Griffin, 1978). The total effect of alteration in information affects the human performance.

Vibration causes image movement on the retina of the eye which degrades vision. Retinal image movement can occur as a result of either vibration of the eyes (known as observer vibration), vibration of the visual field (display vibration) or vibration of both the eye and the visual field (simultaneous observer and display vibration). This retinal image movement depends on the vibration frequency and viewing distance. The greatest problems with display vibration occur at frequency range of about 2–20 Hz (Stott, 1984). For a seated person, the magnitude of eye motion at its resonance frequencies is dependent on body posture, seating characteristics and characteristics of back rest and highly variable between individuals (Griffin, 1990). Degraded visual performance due to vibration was evidenced when the head made contact with the headrest (Johnston and Wharf, 1979). It was reported that the larger size and shape of characters, and changes in types of character fonts resulted in reduction of reading errors (Lewis and Griffin, 1980; Meddick, 1977).

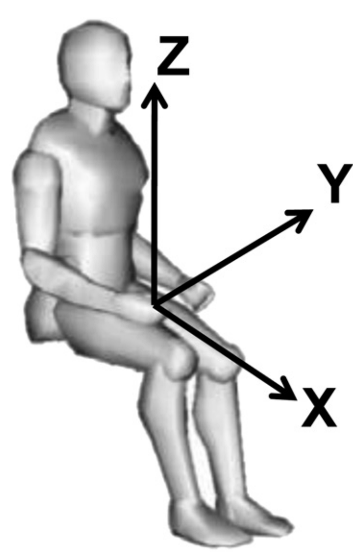

Fig. 1. Typical co-ordinate system for vibration on the human body (adapted from ISO 2361-1, 1997).

In Swedish inter-city trains, Khan and Sundström (2004) found that passengers using computers were disturbed by jerks and vibration. A similar study conducted in India by Narayanamoorthy et al. (2008a) revealed that disruption to perform reading and writing activities by the vibration and noise among executive class train passengers although the ride was perceived as comfortable.

Nakagawa and Suzuki (2005) conducted a study on a simulator with 6 degrees of freedom built as a mockup of railway coach to address the problems of computer users in trains. For improved performance on computer in vibration environment, it recommended a value of 95 $\pm$ 50 mm as optimum distance between the center of seat and edge of the table and130 $\pm$ 75 mm as the optimum distance between center of the seat and computer. Time required by participants to complete the pointing and clicking activity by using mouse was used by Arora (2006) as a parameter to predict the effect of WBV and a parameter for measuring the performance. The study revealed that there was negligible difference in the human performance between 'low' vibration of their study (0.508 ms^{-2} r.s.s) and no vibration (control condition) cases, but at 'high' vibration (0.878 ms^{-2} r.s.s) the performance reduced significantly.

1.3. Human–computer interface

Interaction between users and computers occurs at the user interface, which includes both software and hardware. The user interface refers to the graphical, textual and auditory information presented by a program to the user. In addition, the control sequences employed to control the program such as keystrokes with the computer keyboard, movements of the computer mouse, and selections with the touch screen can also be attributed to user interface. Even though pointing and clicking task can be performed by many devices, touch screen, mouse and touchpad are popular among them. However, mouse was widely used by more number of computer users (Woods et al., 2002). Using Fitts' law, Lin et al. (2010) investigated performance of pointing devices such as touch screen, mouse, and track ball to find its suitability under dynamic environments like in ships and moving land vehicles. Four target sizes, 10, 15, 20, and 25 mm, four target distances 35, 45, 100, and 170 mm and four target angles 0°, 45°, 90°, and 135° were used in the investigation. Three levels of vibration static (no vibration), r.m.s. acceleration of 0.22 and 0.34 ms^{-2} were used. From the results of the investigation, it was found that the effect of vibration decreased the performance of the pointing devices, the effects were not at the same strength and the mouse was strongly affected by vibration. Based on the results of movement time, error rate, slope in the Fitts' law model and throughput, the mouse was recommended for use in the vibration environment to maintain a high efficiency in computer pointing tasks. Recently, Narayanamoorthy and Huzur Saran (2011) investigated influences of vibration