Lindeman, R.W., Yanagida, Y. (2003). Empirical Studies for Effective Near-Field Haptics in Virtual Environments, (Poster) *Proc. of IEEE Virtual Reality 2003*, pp. 287-288.

# Empirical Studies for Effective Near-Field Haptics in Virtual Environments

Robert W. Lindeman
*Department of Computer Science*
*The George Washington University*
*Washington, DC, USA*
*gogo@gwu.edu*

Yasuyuki Yanagida
*Media Information Science Lab, Dept. 3*
*ATR Institute International*
*Kyoto, Japan*
*yanagida@atr.co.jp*

## Abstract

*This paper presents results from two experiments into the use of vibrotactile cues for near-field haptics in virtual environments. In one experiment, subjects were tested on their ability to identify the location of a one-second vibrotactile stimulus presented to a single tactor of a 3-by-3 array on their back. We recorded an 84% correct identification rate. In a second experiment, subjects were asked to match the intensity of a vibrotactile stimulus presented at one location with the intensity at another location. We found that subjects could match the intensities to within 7Hz if the reference and adjustable stimuli were presented at the same location, but only to within 18Hz otherwise.*

## 1. Introduction

Our current research is focussing on developing a generalized approach for displaying near-field haptic cues in immersive virtual environments (VEs). In order to produce stimuli that create a sense of contact in the user, we have conducted empirical studies into stimulus localization and intensity perception on the dorsal side of the human torso (*i.e.*, the back). Stimuli were delivered using vibrotactile units (*tactors*), each in the form of a DC motor with an eccentric mass, with an increase in voltage producing an increase in vibration intensity.

The use of these low-cost pager motors has been proposed by others [5, 4, 1], but knowledge of how to adequately control the output stimulus on different body locations and for different applications is limited.

## 2. Near-Field Haptic Feedback Approach

To support the complex nature of near-field interactions, we have designed the TactaBoard system [2, 3]. This system incorporates the control of a large number of different types of feedback devices into a single, unified interface. In addition, the system can be run completely from battery power, and can use a wireless connection to provide control from the host computer running the simulation software. Our current version supports the independent control of 16 outputs on a single controller board using a standard serial port.

## 3. Empirical Studies

We conducted two experiments involving 21 subjects each. Vibrotactile cues were controlled using the TactaBoard system, which was connected to the serial port of a PC. User input was made using solely the mouse, and subjects were seated throughout the entire session. A 3-by-3 array of tactors was affixed to an office chair, with a spacing of 6cm between the centers of each pair of neighboring tactors (Figure 1).

**Figure 1: Office chair with 3-by-3 array of tactors**

The tactors in the lowest row were affixed such that they touched the back of the subject just above the belt line. The center column of tactors touched the subject along the spine. Care was taken to insure that subjects wore light clothing for the experimental session, and most wore dress shirts or "T" shirts.

### 3.1. Experiment 1: Location Discrimination

This experiment looked at the ability of subjects to discriminate between vibrotactile stimuli applied to different locations on the human back, in an attempt to quantify how well users can identify the location of constant-intensity stimuli at discrete points. The computer display contained a 3-by-3 array of buttons with each button label corresponding to a tactor location on the back (Figure 2). Each subject was given 36 trials, each of which consisted of a one-second 91Hz stimulus. The subject was asked to choose the button best matching the location of the stimulus for that trial.

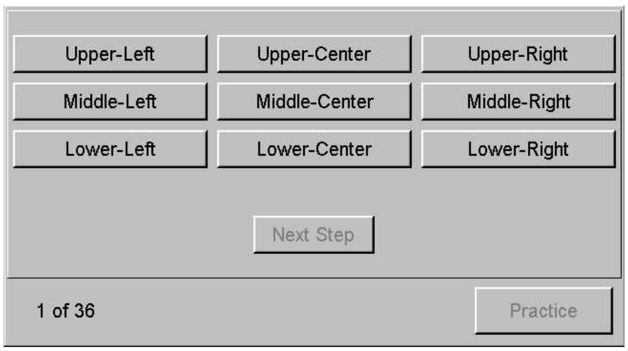


**Figure 2: Location discrimination interface**

### 3.2. Results

The overall successful identification rate (84%) should be useful as a guide for interface designers when deciding how best to incorporate vibrotactile cues into VEs. Stimuli presented to the upper row of tactors were found to be significantly more frequently misidentified than for the other two rows ($p < 0.01$; $df = 2$; $f = 4.78$), and there was no difference between the middle and lower rows. Furthermore, subjects performed significantly worse for stimuli presented to the center column than for the right column ($p < 0.05$; $df = 2$; $f = 4.11$), but otherwise there were no significant differences. There were no interaction effects for row and column ($p > 0.1$; $df = 4$; $f = 1.83$).

### 3.3. Experiment 2: Intensity Matching

This experiment looked at the ability of subjects to match the perceived intensity of two vibrotactile stimuli applied to locations on the human back. The subjects and experimental chair apparatus in this experiment were the same as those used in Experiment 1. The computer display contained two panels (Figure 3). The left-panel button controlled the output of a reference stimulus, when clicked on and held by the user. The right-panel button controlled an adjustable tactor in the same manner as the reference button, but with two arrow buttons; one to increase the stimulus, and one to decrease the stimulus. Each subject performed 81 trials with randomized pairings of reference and adjustable tactors, and frequencies (in Hz) chosen from among 38, 54, 65, 68, 69, 72, 75, 78, 81, and 83. Thus, tactor location and frequency were the factors being studied.

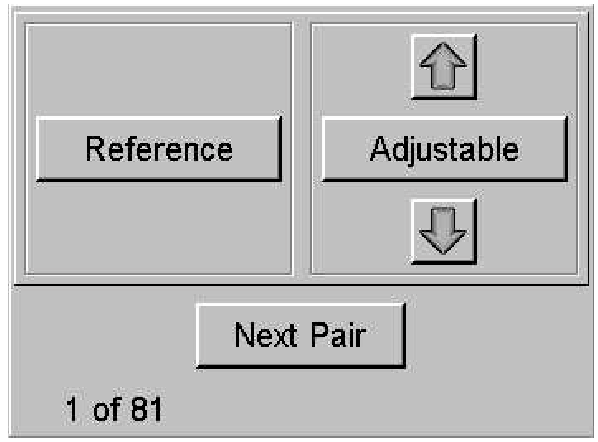


**Figure 3: Intensity matching interface**

### 3.4. Results

A significant main effect was found for reference location ($p < 0.05$; $df = 8$; $f = 16.66$), with reference tactors on the left side producing better matching than those in the center or right. Subjects were able to match a stimulus intensity to within 7Hz, at varying stimulus frequencies, when the reference and adjustable tactors were at the same location, but could only match to within 18Hz when the locations were different. In addition, a main effect for reference frequency ($p < 0.05$; $df = 9$; $f = 13.88$) was found, with higher reference frequencies producing superior matching abilities.

## 4. References


[1] Erp, J.B.F. van, Werkhoven, P.J. Spatial characteristics of vibro-tactile perception on the torso. TNO-Report TM-99-B007. Soesterberg, The Netherlands: TNO Human Factors.

[2] Lindeman, R.W., Templeman, J.N., Sibert, J.L., Cutler, J.R. Handling of virtual contact in immersive virtual environments: beyond visuals, *Virtual Reality*, 6(3), 2002, pp. 130-139.

[3] Lindeman, R.W., Cutler, J.R. Controller design for a wearable, near-field haptic display, to appear in *Proc. of the Eleventh Symp. on Haptic Interfaces for Virtual Environment and Teleoperator Systems*, 2003.

[4] Rupert, A. An instrumentation solution for reducing spatial disorientation mishaps. *IEEE Eng. in Med. and Bio. 2000*, pp. 71-80.

[5] Tan, H., Lu, I., and Pentland, A. The chair as a novel haptic user interface. *Proc. of the Workshop on Perceptual User Interfaces*, Oct. 19-21, Banff, Alberta, Canada 1997, pp. 56-57.