Wearable Haptic Gaming Using Vibrotactile Arrays

**Adam Tindale**

OCAD University

Toronto, ON M5T 1W1 Canada

atindale@faculty.ocadu.ca **Jessica Peter**

OCAD University

Toronto, ON M5T 1W1 Canada

jp11jg@student.ocadu.ca **Michael Cumming**

OCAD University

Toronto, ON M5T 1W1 Canada

mcumming@ocadu.ca **Sara Diamond**

OCAD University

Toronto, ON M5T 1W1 Canada

sdiamond@ocadu.ca **Hudson Pridham**

OCAD University

Toronto, ON M5T 1W1 Canada

hp12pk@student.ocadu.ca

2014-05-16

Abstract

In this paper we describe the design process of expanding vibrotactile displays from single channels devices to multichannel vibrotactile displays. The purpose for this exploration is to add simple, interactive visual and vibrotactile patterning to wearable gaming devices. In order to facilitate movement we have created numerous prototypes to examine the affordances and limitations of a wrist-encircling pattern of tactors.

**Key words:** haptic gaming, vibrotactile arrays, wearable devices, multi-sensory

H.5.2Information interfaces and presentation (e.g., HCI)User Interfaces.

Wearable Gaming, Vibrotactile display, Wrist

## 1 Introduction

Vibrotactile displays allow for a variety of information communication scenarios, most compelling for use are those where the user can receive information without having to look at the signifying device [10, 8]. Gaming provides a venue for tactile feedback, often used to enhance immersion into the experience. This project explores whether it is possible to create wearable gaming experiences that involve visual and vibrotactile spatial and temporal patterns. While there are many examples of projects that do this they are almost certainly tethered to screen experiences. This project uses an wearable device that is able to offer play experiences to the wearer without being tethered to another device.

Our approach is to explore the simplest of patterns and study their affordances. The patterns are presented to the user both visually and through tactile stimulus. As the games progress the pattern is presented only through tactile stimulus. The goal is to determine the spatial and temporal resolution of the wrist for tactile stimulus.

Our demo experiences focus on an attempt to make the interactions very simple, such that they convey information in a way that presents few cognitive demands on the user and which the user would tend to find enjoyable and engaging, even if they were not participating in a mobile game.

## 2 Related Work

Wrist-worn tactors serve many functions including: assessment of cognitive performance in the elderly [6], notification during gaming [9], discrete patterns for alerts for on-the-go users [7, 2]. A wrist-worn haptic device for swimmers is described in [5] and an assistive technology wayfinding project is described in [3].

HandJive is a handheld device used for communication and play between people [4]. Researchers found that participants were able to successfully replicate purely haptic patterns at increasing levels of difficulty in a gameplay situation, and enjoyed improvising their own patterns. These findings suggest that haptic feedback can be incorporated as an enjoyable and meaningful way of conveying game information.

Wrist wearables must fit on wrists and must not have excessive tactor density. Matscheko notes that physiognomic studies indicate that average U.S. wrist circumferences are 18.38cm for men and 14.8cm for women. A minimum threshold distance, the minimum distance on the wrist or forearm between which people are able to discriminate tactors is 38mm [10]. This provides a limited amount of wrist ’real estate,’ if the purpose is to transmit discrete symbolic messages using the tactors.

Various types of tactor wrist arrays can be found in the literature: a 3x3 array [2], a 3 tactor circular array [7] and a 4x1 wrist-encircling array [10].

Lee and Starner describe patterning for wrist-worn tactile displays [7]. They note that for these patterns, intensity is the most difficult parameter to distinguish and that the temporal parameter is the easiest. Reaction time to perceive tactile alerts was not deteriorated by visual distraction.

Bronner notes that a sense of touch is basic to human processes of testing, expressing reality and meaning. Often people must both see with their own eyes as well as touch with their own hands to believe in a phenomenon[1]. He also notes that people surround themselves with particular, touchable objects to reinforce their own feelings and identities.

Chen at al. examine where to place tactors on the wrist. They reason that if a mobile device is to be worn like a watch, then factors can be placed on both sides of the wrist (that is, both the dorsal and volar sides) [2].

In our research we have built prototypes that build on previous research to explore the ways that very simple tactile and visual signals can provoke rich play. Our prototypes explore the use of the whole wrist, including the sides, as a site of vibrotactile information display.

## 3 Prototypes

### 3.1 Simon Says Wristband

This is a wearable version of the traditional *Simon Says* game mounted onto a flexible velcro and felt wristband (see Figure 2). The game is controlled by four push buttons each with a corresponding LED light. The LEDs flash in a random pattern and a single vibration motor signals the beginning of a new game. To play the game the wearer repeats the pattern as flashed by the LEDs by pressing the buttons directly adjacent to each LED.

This prototype was meant to test autonomous wearable games, and while it was a successful simple game, users became bored quickly. The major interest in the users was with the tactor, thus we expanded the vibrotactile component in subsequent versions.

### 3.2 Rubber vibration band version 1

This wrist band with a thick rubber band has vibrating motors and LED lights (see Figure 3). Vibrating motors and lights are arranged linearly with motors alternating with lights. It connects to and is controlled by an Arduino Mega microcontroller board. The prototype device is thick and unfortunately can’t be worn (some components come out the back of the device). The device has no input buttons or other input devices.

Users were stimulated by the multiple tactors and spent time imagining other sequences of vibration they were interested in feeling. Users also noted that they wanted an interaction channel, not a simple display device.

### 3.3 Rubber vibration band version 2

This band is similar to the first band but instead of a linear pattern, there is 3x8 array of buttons, lights, and vibrating motors (see Figure 4). Each row of this array has one button, one light and one vibrator that are all independent, allowing for the creation of interactive buttons games like *Simon Says*. The 3x8 matrix starts to afford more possibilities for user interaction. Modal play becomes possible since many types of user notifications are possible with such an array.

### 3.4 Wearable Vibrotactile Game Interface

The final interface (see Figure 5) utilizes the learnings in the rubber band prototypes, combining visual and tactile feedback, with a form factor that is able to be comfortably worn, like our first prototype. Additionally, the buttons on the final interface are soft buttons that are activated by pressing on the tactors. The tactors are placed 1cm from one another, or two 2cm from center to center.

The final prototype combines the user feedback from previous iterations with the software development advances made during the rubber vibration band phases. The final prototype lead to user session length increase. Users were able to successfully play the Simon Says game with only the vibrotactile channel.

## 4 Future Work

The resolution of the haptic channel on the wrist in both the spatial and temporal dimensions are not fully studied. The next prototypes will include different sizes of vibrotactile arrays so that we may figure out how many motors are required to maximize the information reception through the tactile channel in the wrist. Specifically, are going to build and test devices that include six, four, and two tactors.

In addition to gaming applications, the devices will be tested for encoding more critical information and measuring the effectiveness of non-gaming contexts with vibrotactile arrays. We are currently developing a method of authoring the vibration sequences so that they may be more effectively created, stored, processed, and shared.

## 5 Conclusion

Vibrotactile arrays combine with simple visual patterns present new possibilities for information display to users through their body. We have demonstrated the use of a wearable multichannel vibrotactile and visual display intended for gaming in order to explore the uses and affordances in a non-critical usage scenario.

## 6 Acknowledgements

We would like to thank Ryan Maksymic, Boris Kourtoukov, and Steve Szigeti for their help in the development of this project. This work is generously supported by grants from the Natural Sciences and Engineering Research Council of Canada (NSERC), International Science and Technology Partnerships Canada, and OCAD University.

References

[1] Bronner, S. J. The haptic experience of culture. *Anthropos Freiburg 77*, 3-4 (1982), 351–362.

[2] Chen, H.-Y., Santos, J., Graves, M., Kim, K., and Tan, H. Z. Tactor localization at the wrist. In *Haptics: Perception, Devices and Scenarios*. Springer, 2008, 209–218.

[3] de Jesus Oliveira, V. A., and Maciel, A. Using vibrotactile communication to assist in orientation and locomotion. Tech. rep., Instituto de Informatica (INF) Universidade Federal do Rio Grande do Sul (UFRGS) Porto Alegre, Brasil, 2013.

[4] Fogg, B., Cutler, L. D., Arnold, P., and Eisbach, C. Handjive: a device for interpersonal haptic entertainment. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, ACM Press/Addison–â€ Wesley Publishing Co. (1998), 57–â€ –â€ 64.

[5] Förster, K., Bächlin, M., and Tröster, G. Non-interrupting user interfaces for electronic body-worn swim devices. In *Proceedings of the 2nd International Conference on PErvasive Technologies Related to Assistive Environments*, ACM (2009), 38.

[6] Ivorra, A., Daniels, C., and Rubinsky, B. Minimally obtrusive wearable device for continuous interactive cognitive and neurological assessment. *Physiological measurement 29*, 5 (2008), 543.

[7] Lee, S. C., and Starner, T. Buzzwear: alert perception in wearable tactile displays on the wrist. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, ACM (2010), 433–442.

[8] MacLean, K. E. Putting haptics into the ambience. *Haptics, IEEE Transactions on 2*, 3 (2009), 123–135.

[9] Martins, T., Sommerer, C., Mignonneau, L., and Correia, N. Gauntlet: a wearable interface for ubiquitous gaming. In *Proceedings of the 10th international conference on Human computer interaction with mobile devices and services*, ACM (2008), 367–370.

[10] Matscheko, M., Ferscha, A., Riener, A., and Lehner, M. Tactor placement in wrist worn wearables. In *Wearable Computers (ISWC), 2010 International Symposium on*, IEEE (2010), 1–8.