Don't Touch:
Social Appropriateness of Touch Sensor Placement on Interactive Lumalive E-Textile Shirts

by

Sylvia Hou-Yan Cheng

A thesis submitted to the

School of Computing

in conformity with the requirements for

the degree of Master of Science

Queen's University

Kingston, Ontario, Canada

August 2011

Your file Votre référence
ISBN: 978-0-494-76975-1

Our file Notre référence
ISBN: 978-0-494-76975-1

Abstract

We discuss the design of an e-textile shirt with an interactive Lumalive display featuring a touch-controlled image browser. To determine where to place touch sensors, we investigated which areas of the Lumalive shirt users would be comfortable touching or being touched. We did so by measuring how often participants would opt out of touches. Results show significant differences in opt-outs between touch zones on the front of the shirt. For both touchers and touchees, opt-outs occurred mostly in the upper chest touch zone. We also found significant differences in comfort ratings between touch zones on the front as well as on the back of the shirt. On the front, the upper chest and lower abdominal zones were the least comfortable touch zones. We found no gender effects on overall comfort ratings, suggesting the upper chest area was equally uncomfortable to males as it was to females. Interestingly, touching some areas rated as most uncomfortable produced a significantly greater calming effect on heart rate. Findings suggest participants were less comfortable with touches on the upper chest, the lower abdomen, and the lower back. We conclude that the most appropriate areas for touch sensors on a shirt are on the arms and shoulders, as well as on the upper back. Based on these findings, we created an interactive shirt for a proximity-based game of tag using Lumalive e-textile displays. This custom shirt features touch sensors located on the shoulder and lower arm regions of the shirt.

Acknowledgments

I would like to express my gratitude towards my thesis advisor and supervisor, Dr. Roel Vertegaal, for his guidance and support in this thesis. This work would not have been possible without his perseverance and wisdom. Thank you for believing in me!

I would also like to thank all of my colleagues in the Human Media Lab who have helped me on this thesis – thank you to Marty, Rob, Byron, and Jesse for re-soldering all the broken wires! In particular, I'd like to express my appreciation to Andreas for building the hardware component of this project. I'd also like to thank my friends, particularly Tim, who took part in my study and who have helped me recruit participants.

A special thank you is reserved for Justin Lee, who was present in all the sessions of my experiment as my assistant. Without his continuous support and reassurance, this seemingly impossible project would not have reached its completion.

Lastly, I would like to acknowledge my friends, family, and Momo who have also provided me with the encouragement to complete this thesis.

Contents

Abstract **i**

Acknowledgments **ii**

Contents **iii**

List of Figures **vi**

Chapter 1: Introduction **1**
1.1 Overview 1
1.2 Motivation 3
1.3 Objective 3
1.4 Statement of Originality 3
1.5 My Contribution to this Thesis 5
1.6 Outline of Thesis 6

Chapter 2: Related Work **8**
2.1 Fabric Computing and E-Textile Displays 8
2.2 Fabric Displays 10
2.3 The Body Display 12
2.4 Social Touch Experiments 13
2.5 Heart Rate Response to Touch 15
2.6 Summary 16

Chapter 3: Design Rationale **17**
3.1 Scenarios 17
3.1.1 Gaming 17
3.1.2 Social Networking 18
3.1.3 Medicine 18
3.1.4 Navigation 19
3.2 Experimental Design 19
3.2.1 Hypotheses 19

Chapter 4: An Interactive Lumalive T-Shirt **21**
4.1 Apparatus: An Interactive T-Shirt 21
4.2 Hardware Implementation 21
4.2.1 Heart Rate Measurement 23
4.2.2 Heart Rate Logging Interface 24

Chapter 5: Experimental Evaluation **26**
5.1 Task 26
5.2 Experimental Design 26
5.3 Procedure 27
5.4 Participants 28
5.5 Opting Out 28
5.6 Opt-outs from Recruitment Pre-Screening 30
5.7 Questionnaire 31
5.8 Heart Rate 31

Chapter 6: Results **33**
6.0.1 Opting Out of Touching or Being Touched 33
6.0.2 Touchee Opt-Outs 33
6.0.3 Toucher Opt-Outs 35
6.0.4 Effects of Gender on Opt-outs 36
6.0.5 Observations on Opt-Outs 36
6.0.6 Opt-outs from Participant Recruitment Pre-Screening 37
6.1 Comfort Ratings 37
6.1.1 Touchee Comfort Ratings 38
6.1.2 Toucher Comfort Ratings 40
6.1.3 Effects of Gender on Comfort Ratings 41
6.1.4 Observations on Front vs. Back Touching 41
6.1.5 Observations on the Tickle Factor 42
6.1.6 Observations on Right vs. Left Touch Zones 43
6.1.7 Observations on Specific Touch Zones 43
6.1.8 Other Observations 43
6.2 Heart Rate 45
6.2.1 Observations on Heart Rate 46

Chapter 7: Discussion **49**
7.0.2 Comfort Ratings 49
7.0.3 Heart Rate 50
7.0.4 Design Recommendations 51
7.1 Limitations of Our Findings 52

Chapter 8: TagURIt: A Proximity-based Game of Tag Using Lumalive e-Textile Displays **54**
8.1 TagURIt, An Application for Interactive E-Textile Displays 54
8.2 Introduction 55
8.3 Social Gaming 56
8.4 TagURIt: A Proximity Based Tag Game with Lumalive Displays . . . 58
8.5 Touch Sensing 60
8.6 Location Tracking 60
8.7 Evaluation 61
8.8 Summary 64

Chapter 9: Conclusions **65**
9.1 Future Work 65
9.2 Conclusions 66

Bibliography **68**

Appendix A: General Research Ethics Board Approval **75**

Appendix B: Questionnaires **77**

List of Figures

1.1 Lumalive e-textile display with diffuser removed to show hardware components [5] 2

1.2 Touch Sensor Placement 4

2.1 A user pinching his shirt to illustrate the pinstripe interface [1] . . . 9

2.2 Chalayan's morphing dress from his Spring/Summer 2007 One Hundred and Eleven Runway [1] 11

2.3 Lilypad Arduino [15] (a), i*Catch main board [34] (b), TeeBoard circuitry [33] (c) 11

2.4 Philips Emotion Sensing Dress, Bubelle [5] 14

3.1 Toucher touching Touchee with Lumalive shirt 20

4.1 Touch Sensor layout on Lumalive Garment 22

4.2 Arduino, Lumalive touch controller, and Phidgets setup 23

4.3 Arduino and Lumalive touch controller (in the control box), Lumalive Display, and Phidgets 24

4.4 Heart Rate Strap [6] (a) and Interface Board [8] (b) 25

4.5 Heart Rate Logging Interface 25

5.1 Flash card showing target touch zone (a) and flash card showing target image (b) 27

6.1 Number of opt-outs by *touchees* for each corresponding touch zone . . 34
6.2 Number of opt-outs by *touchers* for each corresponding touch zone . . 34
6.3 (Minimum, Median, Maximum) Comfort Ratings by *touchees* for each corresponding touch zone 38
6.4 (Minimum, Median, Maximum) Comfort Ratings by *touchers* for each corresponding touch zone 39
6.5 Average Heart Rate Change (bpm) for each Touch Zone (Female touching Female) 47
6.6 Average Heart Rate Change (bpm) for each Touch Zone (Female touching Male) 47
6.7 Average Heart Rate Change (bpm) for each Touch Zone (Male touching Female) 48
6.8 Average Heart Rate Change (bpm) for each Touch Zone (Male touching Male) 48

7.1 Appropriate (green) and inappropriate (red) areas for touch sensor placement. 51

8.1 Participants playing the TagURIt game 56
8.2 The goomba token and the boo token 59
8.3 Interactive Lumalive Shirt with Touch Sensors (Front) 61
8.4 Interactive Lumalive Shirt with Touch Sensors (Back) 62
8.5 System Architecture of TagURIt 63

Chapter 1

Introduction

1.1 Overview

With the advent of new, flexible display materials such as Flexible Organic Light Emitting Diodes (FOLEDs), Flexible E-Ink, and Flexible Light Emitting Diode (LED) displays comes a renewed interest in examining new form factors for computer systems. These new materials make possible displays in shapes that allow integration of user interfaces into everyday objects that are not limited to flat, rectangular, or rigid shapes. Many of these display technologies have proved elusive, mostly due to their brittle nature. However, Philips Lumalive technology [5] is one flexible display technology that has made it to market. This display consists of a 14 x 14 pixel matrix of multicolored LEDs woven into a flexible fabric, with padding resembling a lightweight white pillow (see Figure 1.1).

Lumalive displays were designed specifically to be worn on the body, under a shirt. This shirt features Velcro strips that allow the Lumalive to be mounted on the lower abdomen or lower back of the wearer. When worn, the display emits light through the shirt's surface, providing one of the first flexible, electronic display

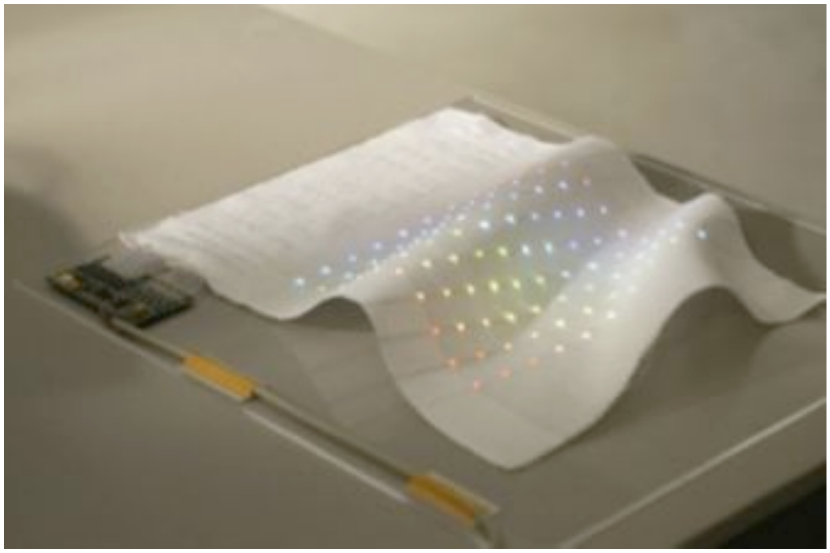

Figure 1.1: Lumalive e-textile display with diffuser removed to show hardware components [5]

surfaces for garments that is of sufficient quality to show images, logos, text, and animations. Philips' current product is aimed squarely at advertising markets, with its primary use by models for displaying promotional materials. As such, the current Lumalive implementation is not designed as an interactive computer. Images need to be uploaded via USB onto a small battery-powered controller that is worn in the belt of the t-shirt. However, interactive Lumalive garments would have great potential for a wearable interactive medium with an inherently social look and feel, providing an opportunity as a platform for lightweight socio-cultural messaging in public environments. Such interactive shirts would need to feature some form of input.

1.2 Motivation

Our motivation for placing touch sensors directly on garments is two-fold: to provide wearers and the public with the ability to directly manipulate content on the display without the need for a hand-held device, and, perhaps, to encourage touch as a means of social engagement with each other.

1.3 Objective

In this thesis, we focus on the question whether such input could be placed on the shirt itself in the form of touch sensors, and if so, what areas might be suitable.

We present the implementation of a Lumalive shirt with interactive touch sensors for browsing images, and discuss the results of an experiment designed to evaluate the social appropriateness of sensor placements. In our experiment, we asked half of our participants to wear an interactive Lumalive shirt with 24 touch sensors, placed in locations shown in Figure 1.2. The other half of the participants were strangers that were asked to touch the sensors on the shirt in to order to find an image on the Lumalive display. Our main dependent variable was how often participants would opt-out of this task.

1.4 Contribution to Human Computer Interaction

This thesis contributes to the field of human computer interaction and social touch in many ways. In past social touch experiments, participants were asked to complete a questionnaire in order to evaluate which areas they would and would not like to be touched. This thesis, we believe, is one of the first in the area of social

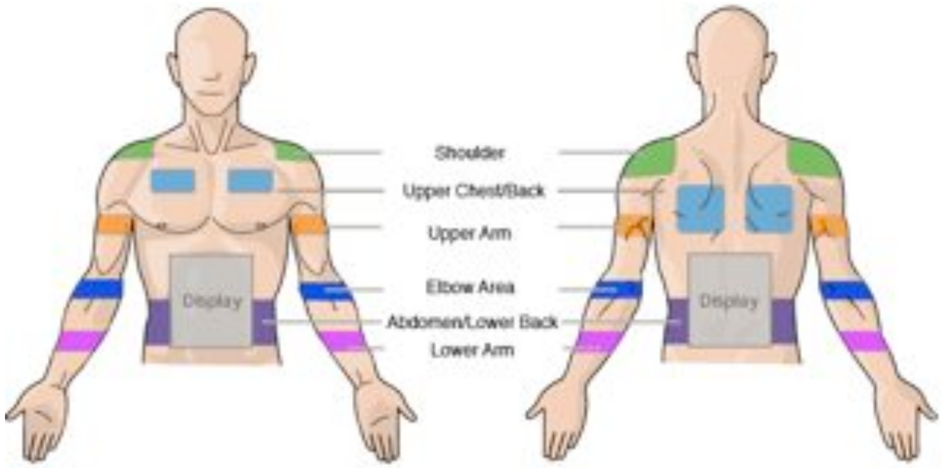

Figure 1.2: Touch Sensor Placement

touch to evaluate whether participants would and would not like to be touched by having the participants actually perform physical touch tasks on each other. From a technical perspective, this research is one of the first to evaluate interactive high resolution textile displays. By integrating the touch with the display, we believe to have increased the ecological validity of the experiment over simply embedding touch sensors to reflect the usability of future touch sensitive displays on shirts; it gave participants a functional reason to touch each other. In this regard, we believe that evaluating a sensor with feedback (as shown on the high resolution e-textile display) is fundamentally different from evaluating a sensor without feedback (as done in past human computer interaction and social touch research). Furthermore, when human computer interaction moves into embedded systems, and fashion garments, the location of touch sensors is an important factor to consider when creating these new interactive systems.

1.5 My Contribution to this Thesis

This section provides a clear delineation of the tasks that myself and others were involved in for the completion of this thesis. A couple of lab members were involved in the hardware creation of both the shirts used in the study (described in Chapter 4) and the shirts used in TagURIt (described in Chapter 8). Specifically, Andreas Hollatz designed, engineered, and built the hardware used in interfacing the lumalive control unit with the touch sensors on the interactive Lumalive T-shirts. He built and engineered the linear solenoid to execute a series of pulses to physically depress the buttons on the lumalive control unit open receiving a signal from the capacitive touch sensors. An Arduino microcontroller was used to interface between the capacitive touch sensors and the linear solenoid. While Andreas coded the first version of the Arduino code, I modified the code to create an updated version that was used in the experiment.

My contribution to this thesis includes the background literature review presented in Chapter 2, the design, recruitment of participants, and execution of the experiment (presented in Chapter 5). I also submitted and received ethics clearance for the execution of the experiment. Regarding the hardware, I designed, engineered, and created the interactive t-shirts used in the experiment (by hand-sewing conductive fabric and thread to the shirts and interfacing them with the capacitive touch sensors). I also programmed the lumalive unit to display the graphics that I created for the study. Furthermore, I developed and coded the software used to track and record the heart rate values that were obtained from the participants in the experiment. With the help of my supervisor, I ran the statistical analysis of the data obtained from the study (Chapter 6), wrote the discussion (Chapter 7), and wrote the conclusions

(Chapter 9).

For TagURIt, I designed and engineered the TagURIt system (Chapter 8), including coding the Lilypad Arudino to interface the capacitive touch sensors with the touch sensors on the shirt. This, along with a couple of shirts with hand-sewn conductive fabric patches (for the touch sensors) and conductive thread (as the circuitry), were part of the first prototype for the TagURIt system. A second and more refined prototype of TagURIt was created for the demonstration that was given at the 2011 ACM Conference on Human Factors in Computing Systems (CHI). For this second prototype, I designed and engineered the system, while Kibum Kim built the it. Additionally, I created the animations that were displayed on the lumalive display for the TagURIt system. I designed the demonstration setup and logistics while Kibum Kim ran the demonstration at CHI.

1.6 Outline of Thesis

This thesis is presented in nine chapters. The first chapter introduces the topic of wearable computing (with a flexible display) and reveals the motivation behind creating a shirt with interactive touch sensors. This chapter also introduces the objective of placing touch sensors on a shirt and what areas are most suitable on the upper body for the placement of these sensors. Finally, this chapter discusses the contribution that this thesis work has made in the human-computer interaction field.

The second chapter provides an overview of the related work that has been done in the area of fabric computing, e-textile displays, social touch experiments, and heart rate changes in response to touch.

The third chapter provides the rationale behind design decisions made in constructing the interactive Lumalive shirt. This chapter also provides scenarios of when and how the interactive Lumalive shirt may be used in social and public settings. The third chapter states the hypothesis of our work.

The fourth chapter introduces the interactive lumalive shirt in detail. This chapter discusses the hardware implementation of the interactive Lumalive shirt and the hardware that was used to measure heart rate during the experiment. An overview of the software implementation for detecting and logging the heart rate values is also provided.

The fifth chapter provides details about the experimental evaluation. The task, experimental design, procedure, participant recruitment, and measurements for the experiment are presented in this chapter. The results are stated in the sixth chapter and a discussion of these results is presented in the seventh chapter.

As an extension to this thesis work, the eighth chapter presents an application for interactive e-textile displays. This application, called TagURIt, is an electronic game of tag that uses proximity sensing and Lumalive displays on garments.

The ninth, and final chapter discusses future work in this area and a provides a conclusion.

Chapter 2

Related Work

2.1 Fabric Computing and E-Textile Displays

With the emergence of pop culture in the early 50s, T-shirts became popular as a medium for public expression. Companies like Tropix Togs printed t-shirts with Disney characters and slogans for presidential campaigns as early as 1948 [42]. From the 1960s to the 1980s, t-shirts flourished as a mass medium for cultural expression. In the mid-90s, custom manufacturing of personal t-shirt designs emerged, allowing shirts to become a highly personalized medium. We can regard the development of high-resolution e-textile displays as an extension of this phenomenon.

Researchers first began to investigate the augmentation of garments with electronics in the mid-90s. Zimmerman [47] developed a wireless communications system, PAN (Personal Area Networks), which allowed for electronic devices located on or near the human body to exchange digital information through near-field electrostatic coupling. Orth et al. [35] stated that fabric is soft to touch, strong, and flexible allowing for the creation of computing devices that are both malleable and durable. They argued that for computers to really move off the desktop, it was necessary to change their form factor into materials that are more readily wearable, and more integrated into the everyday experiences of users. Their Fabric Computing Devices featured an embroidered keypad made of conducting metallic fabric, which could be worn on a shirt and used as a touch input device. MIT's first Wearable Computing Fashion show in the late 90s featured a musical jacket with integrated sensors that allowed users to create sounds on a MIDI synthesizer when touched. More recently, Holleis et al. [24] explored the usability and applicability issues surrounding capacitive touch input on clothing. They created several prototypes of wearable accessories and clothing, including a phone bag, helmet, glove, and apron, that used capacitive touch sensors to allow users to interact with these systems. Karrer et al. [27] also recently explored a textile user interface for eyes-free continuous input on garments using pinching and rolling gestures. A user can pinch or roll a piece of cloth on a garment between his/her fingers to interact with that smart garment (see Figure 2.1). Depending on the amount of cloth that is pinched or rolled, the user can control the amount of input in a natural way. The pinstripe input element is made of fields of parallel conductive lines sewn onto the fabric.

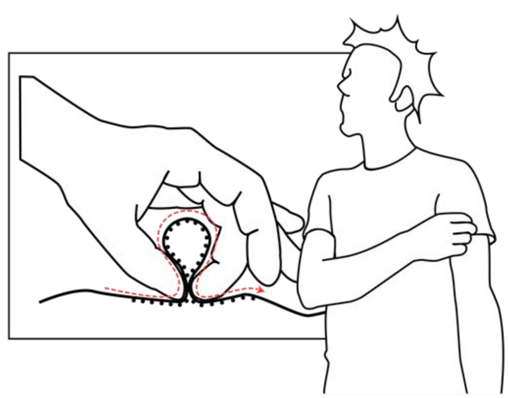

Figure 2.1: A user pinching his shirt to illustrate the pinstripe interface [27]

2.2 Fabric Displays

Advances were also made on the display side, but most of the early developments focused on integrating input into wearable fabrics. Dunne and Gaver's The Pillow [19] is an example display from this period, an art project that challenged viewers to consider invasion by electronic information provided through a regular LCD display sewn into a pillow.

More recently, Berzowska [11] developed a display material called Electric Plaid that allowed for a more high-resolution and flexible fabric display. It used conductive yarns that, when heated, changed the color of thermo-chromic ink sewn onto a fabric. While this process is slow when compared to the refresh rate of computer displays, it did allow for preset high-resolution patterns to appear and be altered on a garment on the fly.

Since then, there has been considerable interest by researchers and fashion designers in embedding various display technologies into fabrics of various kinds [9] [12]. However, without the capacity to show high-resolution bitmapped images, the emphasis on functionality of such displays has been on their use as ambient devices. For example, two-time British designer of the year, Hussein Chalayan, designed a collection of computer-controlled morphing dresses for his summer/spring 2007 fashion show in Paris (see Figure 2.2) [1]. Similarly, in the fashion industry, Rosella and Genz constructed the world's largest wearable display; they designed a dress (the Galaxy Dress) with 24000 full color LEDs [2].

As e-textiles are becoming more popular, do-it-yourself electronic craft kits are now available on the consumer market. For example, Buechley et al. [15] created the LilyPad Arduino, a fabric-based construction kit that allows novices to design and

Figure 2.2: Chalayan's morphing dress from his Spring/Summer 2007 One Hundred and Eleven Runway [1]

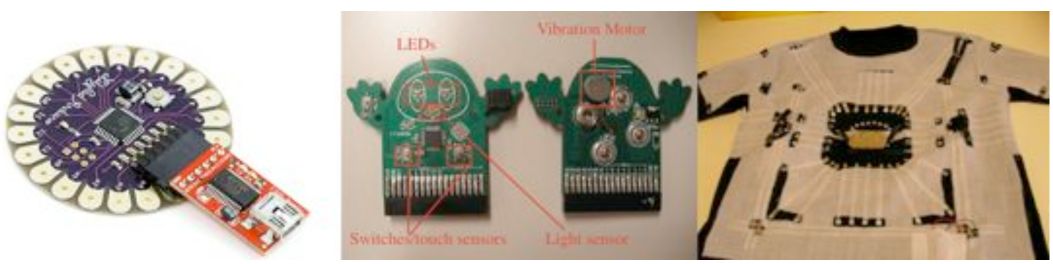

Figure 2.3: Lilypad Arduino [15] (a), i*Catch main board [34] (b), TeeBoard circuitry [33] (c)

construct e-textiles. The Lilypad consists of a fabric-mounted (Arduino) microcontroller (see Figure 2.3a), sensors, actuators, a stitch-able battery holder, insulating fabric paint, and conductive thread. While the Lilypad Arduino requires sewing with conductive thread to connect the components together, the TeeBoard, created by Ngai et al. [33], uses metal snap fasteners as the connective interface (see Figure 2.3c). Ngai et al. [34] expanded this work when they created i*CATch (see Figure 2.3b), a wearable computing do-it-yourself kit. This kit was targeted towards children and the general public. The i*CATch framework is a construction platform that allows users to plug in electronic modules to create their wearable computing project. Using the Lilypad Arduino, Kim et al. [28] prototyped WearAir, an expressive T-shirt designed to sense and display the wearer's surrounding air quality (measured by the voltatile organic compounds) through visually expressive patterns. Recently, Lovell and Buechley [31] designed an e-sewing tutorial for novices to learn how to create their own e-textiles. Their pilot study showed that 13-year-old females with minimal experience in sewing, electronics, and programming are able to successfully complete e-textile do-it-yourself projects.

2.3 The Body Display

An important design consideration for e-textile displays worn on garments is placement on the body. Placement generally interacts with the functionality of the design: when aimed at communicating lightweight information, or when used to enhance a garment in some way, display placement is governed by poetic, aesthetic or playful aspects [10] [11] [13]. When integrating a high-resolution interactive bitmapped display into a garment, accessibility for input becomes of primary concern. One important variable determining the suitability of a touch zone for sensor placement is whether or not users would be willing to touch or be touched in that location. Additionally, dynamic wearability, defined as the interaction between the human body and the wearable object while the human body is in motion, should be considered when designing wearable computers [21]. According to Gemperle et al., the general areas in the upper human torso that are the most unobtrusive for wearable objects are: the collar area, the rear of the upper arm, forearm, rear ribcage, side ribcage, and front ribcage.

There is a considerable body of literature in affective computing that explores bodily touch for the purposes of input, e.g., for sensing emotions or body states through physiological sensors deployed inside clothing [9] [38]. Andersen [9], for example, explored the augmentation of regular clothing elements with light and acceleration sensors, studying their use by children during play, while Schiphorst explored hugging as a means to relay and engage with intimate social information, through garments augmented with various sensors [40]. Furthermore, Philips created a dress that contains biometric sensors that pick up the wearer's emotions [7] (see Figure 2.4). This dress is constructed with two layers: the top layer monitors physiological changes associated with the wearer's feelings (such as stress, arousal, and fear) through sensors that detect temperature and sweat levels; the second layer generates light that changes the pattern and the color of the dress to reflect the wearer's emotions.

2.4 Social Touch Experiments

When considering bodily touch sensors as input devices, it is also important to consider the psychology of social touch, of which Thayer [44] provides a good overview. Harlow's [23] work, for example, on maternal touch deprivation in infant rhesus monkeys, demonstrated the importance of touch as a basic need. Additionally, Pattison [36] showed that brief and light touches on the arm could cause a patient to feel more

Figure 2.4: Philips Emotion Sensing Dress, Bubelle [5]

comfortable. Yet, according to Sussman and Rosenfeld [43], unsolicited touch by a stranger is all too often experienced as offensive, intrusive, or threatening in our everyday lives. According to Remland and Jones [39], this is particularly true in non-contact Western cultures, e.g., the North American culture.

In a classic experiment on social touch, Jourard [26] mapped out the body into 24 areas. Figure 1.2 shows a modified version of the upper torso part of his body accessibility map, identifying 24 regions for exploring placement of touch sensors. When participants were asked how comfortable they would feel being touched in one of these areas across the body, results were strikingly different between the sexes, and between sexes of partners. Almost all males and females reported being touched by same sex friends on the hands, with females reporting a large percentage of touch on the lower arms as well. 51%-76% of males reported being touched on the arms and shoulder region, but only 26%-50% reported touches on the chest and stomach areas. Females, by contrast, reported touches on shoulders and upper arms, but not the rest of the body. 43-74% reported touches on the upper back by a same-sex friend. Results were markedly different for opposite-sex friends, with both sexes reporting a higher incidence of touch all over the body.

Jourard's study did not involve touches by strangers, and did not involve actual touches, but we can extrapolate his results to mean that areas suitable for display to the public may not be suitable for touches by others. More recently, Haans et al. [22] conducted a study that investigated whether gender differences found in same and opposite sex social touch interactions were also present in mediated situations. In this study, participants were led to believe that a male or female stranger was remotely touching them; the participant wore a vest augmented with vibrotactile actuators that stimulated different body locations. They found that there was no significant difference between male and female participants (those receiving the remote touches) nor a significant effect of the interaction partners gender (those providing the remote touches). While our experiment is similar to Haans et al.'s study, their work did not actually involve direct physical interactions between participants. This is true for most, if not all, of the studies on social touch: studies relied on participants imagining touching or being touched.

2.5 Heart Rate Response to Touch

As early as the 1960s, emotional responses to physical proximity of individuals have been studied. McBride et al. [32] found that people experience physiological arousal and anxiety when people are at close interaction distances from one another. However, according to Wilhelm et al. [46], appropriate touch within a socio-cultural context can be calming and reduce heart rates, while inappropriate touch can be anxiety provoking and can increase heart rates. Drescher et al. [18] also showed that dramatic physiological and behavioral changes can be attributed to tactile stimulation within a social context. They found that healthy human subjects respond to being touched by another person with a heart rate deceleration when the subject's wrist was touched. In their study, they used electrodes placed directly on a subject's body. Heart rate was computed for each of the five 30-second experimental periods (experimenter absent before touching, experimenter present before touching, touching, experimenter present after touching, and experimenter absent after touching). We followed a similar procedure for our experiment.

2.6 Summary

We have presented an overview of the related work in the historical background of fabric computing and e-textile displays, and the technology behind e-textile displays. Additionally, we have also presented work done in the area of social touch relating to the response of heart rate to touch, and the emotional responses to social touch. This overview of related work sets the context for further discussion of the design rationale for our interactive Lumalive system and the experimental evaluation.

Chapter 3

Design Rationale

3.1 Scenarios

To envision situations in which people would touch each other's garments, we propose the following scenarios:

3.1.1 Gaming

Interactive e-textile displays can augment various games involving human participants. For example, an interactive shirt can be used in a game of human pacman (similar to Cheok et al.'s gaming system [16]) in which players wear shirts that display their status and role in the game; if a player is an enemy, a red ghost can be displayed on the shirt and as time passes by, if the player is not yet captured by the pacman player (who is wearing a display with a pacman character), the character on the enemy's shirt can change from a red ghost to a blue ghost. In order for the pacman player to capture the red ghost player, he/she would need to physically press on a touch sensor located on the enemy's shirt. This example is one of many examples that illustrate how interactive computer clothing can enhance a game. Other examples of games that can involve interactive computing garments involve the game of tag (see Chapter 8 for a proximity-based game of tag involving an interactive Lumalive shirt), paintball, or laser tag.

3.1.2 Social Networking

In a social setting, such as a coffee shop or a conference, a individual may approach another individual and touch his/her shirt to display information regarding the shirt wearer. One possible situation is at a conference – Justin may tap on Tim's shoulder to display information regarding which academic institution Tim is from and his area of research. Another possible situation involves displaying badges that are earned in the social network, Foursquare. Foursquare is a location-based social network in which users check in at venues using a mobile device; when a user checks into a venue such as a retail store, coffee shop, or restaurant, he/she is awarded points and badges [3]. In this scenario, Marty meets Tre at a local coffee shop; he approaches Tre and he taps on a touch sensor on Tre's shirt to browse through the badges that Tre has earned for checking into the cafe.

3.1.3 Medicine

An interactive medical shirt is an example of the application of an interactive garment that may be used by individuals of different ages. A baby, for example, may wear a jumper that displays his/her vitals (temperature, oxygen level, heart rate, etc) and a caregiver may interact with this dynamic information by pressing on touch sensors located on the jumper. Similarly, a hospital patient may wear an interactive medical shirt that displays his/her vital signs (e.g. electrocardiography) and a medical professional may be able to access this information by touching on an area of the shirt.

3.1.4 Navigation

An example of the use of a interactive touch shirt used in navigation would be in a scenario involving two friends. If two friends are lost, one can open up a google map app on his/her friend's interactive shirt. Using gestures and pressing on touch sensors, he/she can interact with the dynamic map displayed on the shirt while the shirt changes color to indicate how close they are to their target location.

3.2 Experimental Design

Our study was designed to determine the social appropriateness of touch sensor placement on our interactive shirt by measuring the effect of touch sensor location on opt-outs and comfort levels of both wearers and touchers. For the purposes of our study, the term *toucher* refers to the person performing the touching while the term *touchee* refers to the person receiving the touches, i.e., wearing the shirt. Touchers were asked to touch each one of 24 touch zones on the shirt (see Figure 3.1). These touch zones were placed in locations similar to Jourard's body map [26].

3.2.1 Hypotheses

Based on Jourard's findings [26], we expected to find significant differences between touch zones in both opt-outs and comfort ratings. Due to its private location, we only expected opt-outs for the upper chest area. We expected the upper chest and lower front abdominal zones to have lower comfort ratings than other frontal touch zones. We did not expect to find differences between touchers and touchees in opt-outs or

Figure 3.1: Toucher touching Touchee with Lumalive shirt

comfort ratings. We did expect to find gender differences in the number of opt-outs, with more opt-outs for females touchees. We did not expect to find any differences between locations for opt-outs or comfort ratings on the back of the shirt. For heart rate, available literature suggests that social touch lowers heart rate. However, it was not clear if less comfortable touch areas would produce lower heart rates than more comfortable touch areas. We therefore used a single planned two-tailed comparison stating that heart rate between areas with highest and lowest comfort ratings on the front would be different.

Chapter 4

An Interactive Lumalive T-Shirt

4.1 Apparatus: An Interactive T-Shirt

This section introduces our apparatus which is based on the design rationale of the previous section. Our design takes into consideration past related research in social touch and interactive e-textile displays. This chapter also outlines the specific implementation details of the interactive Lumalive t-Shirt apparatus.

4.2 Hardware Implementation

To evaluate the social appropriateness of touch sensor placement on e-textile garments, we designed an interactive version of the Lumalive display for participants of our study. We created two shirts that were used in the study – one in a uni-sex size medium, and the other in a uni-sex size large. This allowed us to accommodate for participants of all sizes.

Our Lumalive garment has 24 sensors; these sensors were made of conductive pure copper polyester taffeta fabric wired with conductive thread into two circuits (see Figure 4.1): one circuit for the left side of the body, and one circuit for the right

Figure 4.1: Touch Sensor layout on Lumalive Garment

side.

Each circuit was connected to a Phidget capacitive touch sensor [4] that was linked to an Arduino controller (Figures 4.2 and 4.3). The Arduino was programmed to execute a pulse to a linear solenoid actuator upon receiving a signal from one of the capacitive touch sensors. This actuated buttons directly on a Lumalive controller unit. All of the conductive thread was insulated using fabric paint and vinyl tape.

Two locations on an undershirt, one on the front upper abdomen, and one on the lower back, featured Velcro attachments for the Lumalive display. The Lumalive was physically connected to the controller unit. Given the limitations on interactivity of the Lumalive display, we chose to create a simple image browser application for the

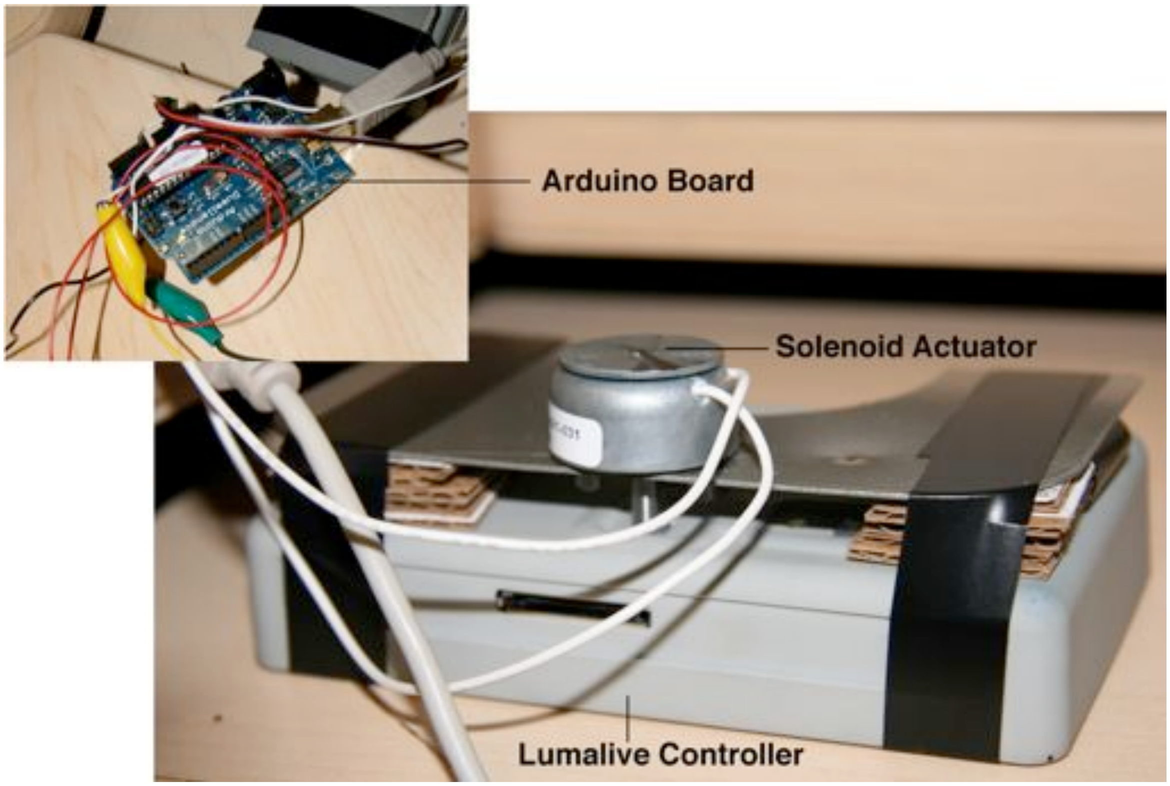

Figure 4.2: Arduino, Lumalive touch controller, and Phidgets setup

shirt. It allowed users to browse through a pre-selected set of images on the Lumalive display. We expect future Lumalive versions to have the capacity to upload images wirelessly or on the fly, allowing for more elaborate interactive applications.

4.2.1 Heart Rate Measurement

Given prior work, we decided to measure the heart rate of the touchee. Similar to Wilhelm et al. [46], we collected heart rate data of the touchee before touching occurred, during the touch, and after the touch was completed. We measured heart rate using a Polar chest strap [6] heart rate monitor worn in direct contact with the touchee's skin (see Figure 4.4a).

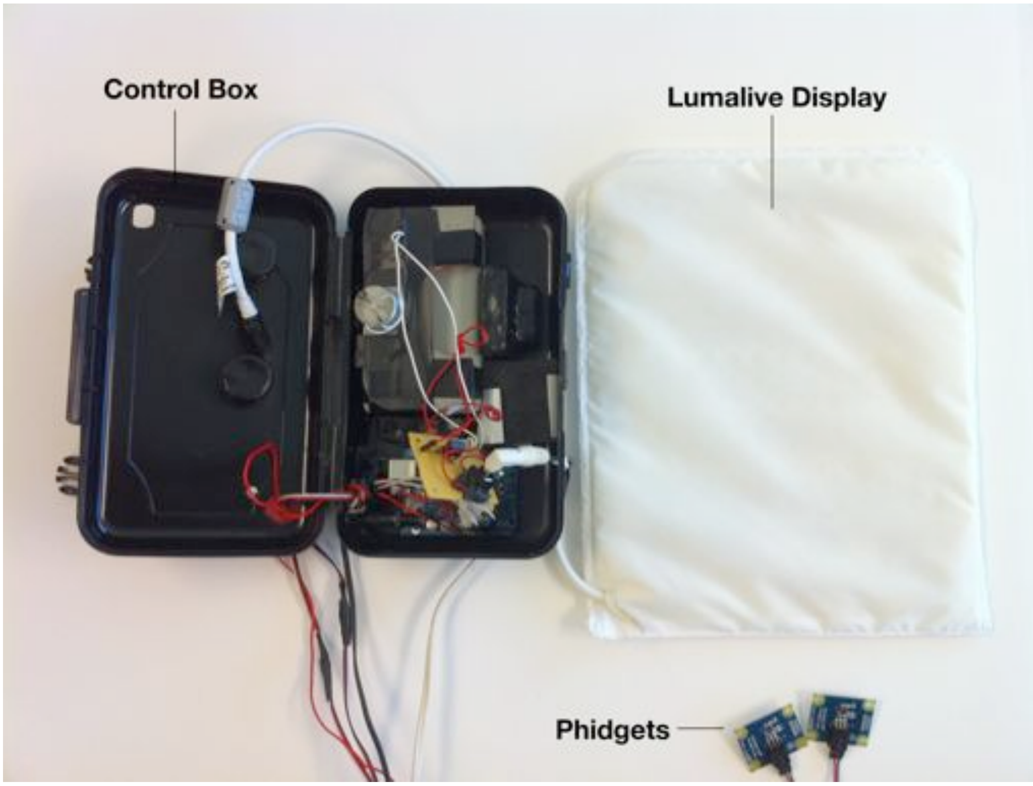

Figure 4.3: Arduino and Lumalive touch controller (in the box), Lumalive Display, and Phidgets

4.2.2 Heart Rate Logging Interface

This sensor transmitted the data to a Polar Heart Rate Monitor Interface (HRMI) circuit board (see Figure 4.4b). This heart rate equipment was chosen to allow for a custom program to log the heart rate data with time and text markers (indicating when the touching started and ended). The custom logging program was written using Processing 1.0 (see Figure 4.5). The software allowed the heart rate values to be displayed on the screen and written to a text file.

Figure 4.4: Heart Rate Strap [6] (a) and Interface Board [8] (b)

Figure 4.5: Heart Rate Logging Interface

Chapter 5

Experimental Evaluation

5.1 Task

As an experimental task, we devised a simple image browsing task. At the beginning of each trial, the experimenter showed a target image to the toucher on a flash card (see Figure 5.1b). Another flash card indicated the zone to be touched (see Figure 5.1a). The toucher then proceeded to tap on the touch sensor in the correct zone until the target image appeared on the Lumalive display, after which the trial was complete. Upon completion, both the touchee and toucher were asked to fill out a questionnaire to rate their comfort levels relating to this zone. The same procedure was repeated for all 24 touch zones on the shirt.

5.2 Experimental Design

We used a mixed design in which we had two mutually exclusive roles for participants, the touchees and touchers, to limit the total amount of time spent by participants on all tasks. Touchees performed the experiment twice; once in a same-sex pairing and once in an opposite-sex pairing. While touchees were required to participate

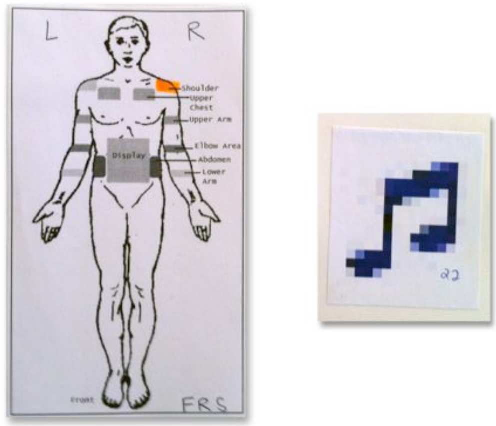

Figure 5.1: Flash card showing target touch zone (a) and flash card showing target image (b)

in two sessions, touchers were only required to participate in one session. We had two between-subject variables: the participant's role (toucher or touchee), and the participant's gender. Our within-subjects variable was the touch zone location. This factor was in turn separated into three components: front or back location, left or right location, and specific zone location, for a total 12 zones on the front (6 zones on the left, 6 on the right), and 12 on the back of the shirt (6 on the left, 6 on the right). We counter-balanced for gender order (males touching females, males touching males, females touching females, and females touching males) using a Latin square. We also counter-balanced the order in which front and back touch zones were presented, and randomized the order of the touch zone location presentation.

5.3 Procedure

The touchee was first instructed to put on the heart rate chest strap in a private room with a lock. Afterwards, the touchee was instructed to put on the special

Lumalive undergarment, after which the display was attached by the experimenter. Participants were then fitted with a shirt with the touch sensors. Following this, the experimenter explained the task and how to operate the touch zones. The touchers were instructed to use an even pressure with their index, middle, and ring finger to press on the touch zones. They were also instructed to use whichever hand they felt was most natural to touch the sensors.

5.4 Participants

19 females and 17 males (aged 18-30) participated in the study. Among the 36 subjects, there were 12 pairings. Each session of the experiment involved 3 participants 1 touchee and 2 touchers; the first half of the experiment involved a toucher performing the task on the touchee and the second half involved a new toucher performing the task on the same touchee. This procedure, which was designed to minimize participation time and setup time, resulted in more females participating in the experiment than males. All the participants were recruited through email notices and through posters displayed around a university campus. They all signed consent forms and received $10 in compensation irrespective of whether they opted out of any trials.

5.5 Opting Out

Before each trial, the experimenter informed the touchee and the toucher that they had the option to opt-out of the trial. A standard script was used to convey this message to the participants at every task to maintain consistency and to prevent the experimenter from influencing whether or not the participants would opt-out of any tasks.

The standard script used is as follows:

> **Experimenter to *Toucher*** - One thing that is very important to know is that if you have any hesitation to perform the task, you dont need to perform the task and you don't need to touch. All you have to say is pass or opt out. If you decide to pass all the tasks, it's perfectly okay; if you decide to perform all the tasks that's perfectly okay too.
>
> **Experimenter to *Touchee***- The same is true for you. You are going to know exactly where you are going to be touched. If you wish to opt out of that at any point, let us know and that's perfectly okay. So the same applies to each of you.
>
> **Experimenter to both *Toucher* and *Touchee*** - I also want to note that there may be cases where only one of you is going to opt out. There's no need to feel uncomfortable when that happens because there may be reasons that you are not aware of. For example, someone's arm may be hurt. Do either of you have any questions regarding the study at this point?

Script conveyed before each trial for all 24 touch zones:

> **Experimenter to *Toucher*** - You will be locating this image (show flash card indicating target image, Figure 5.1b) by touching this touch sensor (show flash card indicating touch zone location, Figure 5.1a).
>
> **Experimenter to *Touchee*** - Your partner will be touching you at this location (show *touchee* the target touch zone flash card, Figure 5.1a).

Experimenter to *Toucher* and *Touchee* - Would either of you like to opt-out?

If an opt-out occurred, the corresponding touch task did not take place. The experimenter asked the person who opted out to indicate on his or her questionnaire the reason for the opt-out. The partner was asked to indicate on his/her questionnaire if he/she would have opted-out if his/her partner did not.

This opt-out measure was an important component in the ethics clearance for this experiment, as it allowed participants not to complete the task. It also constituted our main dependent variable: if participants were too uncomfortable being touched or touching that location of the body, we expected them to opt-out of touching that touch zone. We expected both touchers and touchees to opt-out of only two zones: the left and right upper chest areas. We only expected this result to occur when females were wearing the interactive shirt, with no effect of same sex or mixed sex composition of the pair.

5.6 Opt-outs from Recruitment Pre-Screening

Another component of the opt-out option was observed in the pre-screening of participants during recruitment. During the recruitment process, individuals were informed that they would be participating in a Human Computer Interaction Study and that they will be performing a series of simple touch tasks on Digital Clothing. They were also notified that in this study, male and female participants (aged 18-30) will be paired up and asked to find a digital image on the other participant's body. During this task, each participant will be involved in touching a female and a male participant or will be touched by either a female or male participant. Upon completion, subjects will be asked to fill out short questionnaires regarding their comfort level of being touched at different parts of his/her body or touching another person's body parts. Based on the information given to the potential participants for the study, people were able to choose whether or not they would feel comfortable taking part in the study; those who did not feel comfortable with the study chose not to become a participant.

5.7 Questionnaire

We also asked both touchees and the touchers to fill out a simple questionnaire rating their comfort levels after each trial. We asked touchers to rate how comfortable they felt touching the other person in the indicated location. Touchees were asked to rate how comfortable they felt in being touched in that location. In the case of an opt-out, the value for the comfortable level was substituted with a zero value. The questionnaire was structured using a 5-point Likert scale with an opt-out indicated as a 0 (1 = strongly disagree to 5 = strongly agree), and gauged agreement with a positive statement on the level of comfort of a touch.

5.8 Heart Rate

The heart rate, in beats per minute (bpm), was recorded for the touchee for each session. Only the heart rate of the touchee was recorded due to limitations of the heart rate recording hardware; the heart rate interface board that was used in the experiment was able to pick up data from only one heart rate strap without interference. Since the toucher and touchee were standing in close proximity to one another to perform the touch tasks, only one heart rate strap could be used during the study.

During the experiment, the assistant experimenter recorded markers in the heart rate data indicating when touching started and when the touching ended. The touching at each zone lasted anywhere from approximately 8 seconds to 50 seconds, depending on how long it took the toucher to locate the targeted image on the Lumalive display.

Chapter 6

Results

We first present results for the number of opt-outs for touchees and touchers, after which we discuss comfort levels, heart rate statistics, and observations from the experimental sessions.

6.0.1 Opting Out of Touching or Being Touched

Figures 6.1 and 6.2 show the results for the main dependent variable, the number of opt-outs by touchees and touchers, per touch zone location. A total of 5 opt-outs were recorded for touchees, and 4 for touchers. To ease analysis, we concatenated results for touch zones on the arms into a single zone, evaluating the effect of touch zone location on opt-outs separately for the front and the back of the shirt. We used a related samples k-sample non-parametric Cochran's Q test to test effects of location on our binary opt-out variable.

6.0.2 Touchee Opt-Outs

Figure 6.1 shows the number of opt-outs from touchees per touch zone.

In total there were 24 touchees (14 females and 10 males) involved in the study.

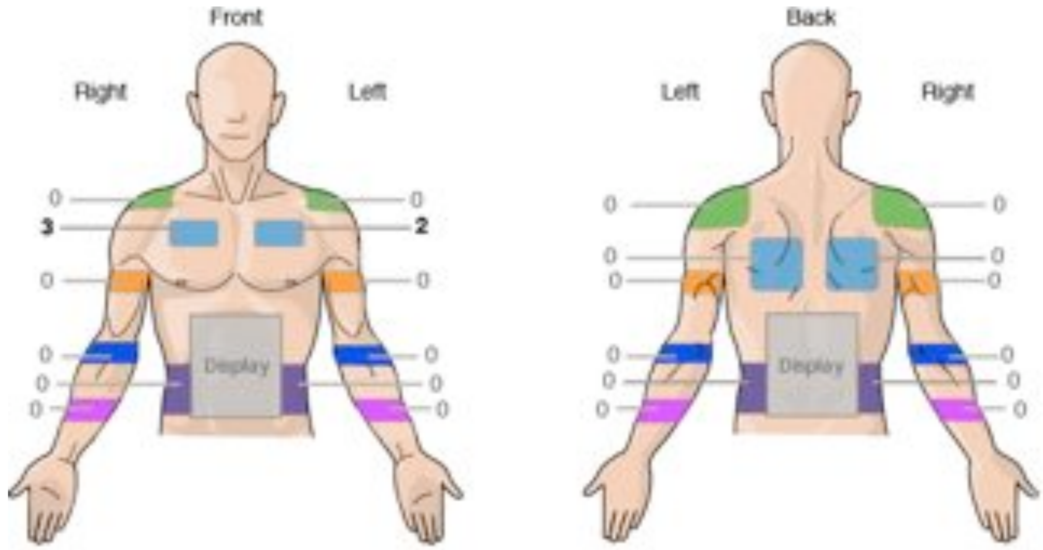

Figure 6.1: Number of opt-outs by *touchees* for each corresponding touch zone

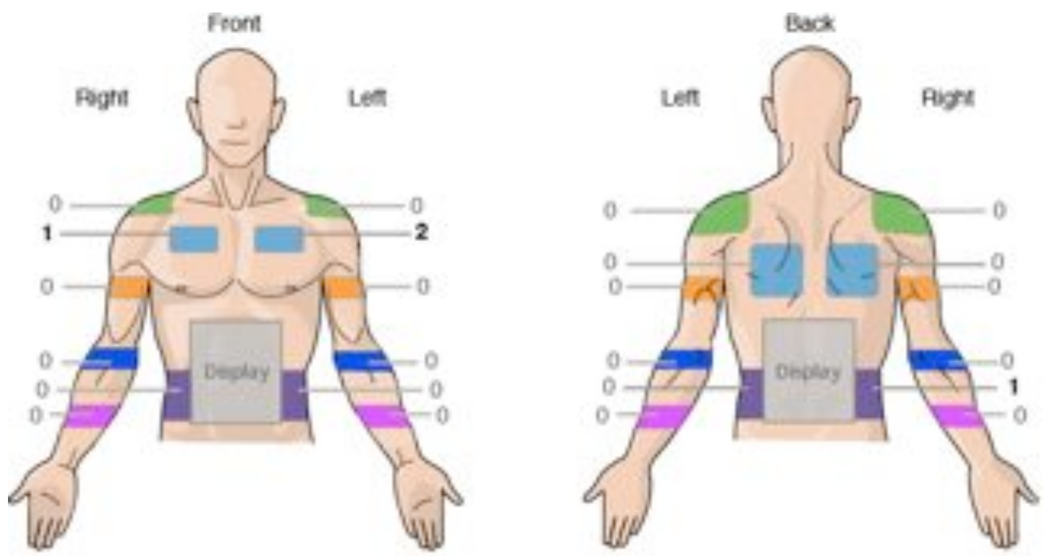

Figure 6.2: Number of opt-outs by *touchers* for each corresponding touch zone

The front right upper chest received a total of 3 opt-outs of the 24 possible opt-out opportunities (the opt-outs occurred 1/8 of time). The front left upper chest received a total of 2 opt-outs of the 24 possible opt-outs (the opt-outs occurred 1/12 of the time).

We found a significant effect of touch zone location on opt-outs on the front of the shirt (Cochran's Q(3)=15.0, $p<0.05$). There were no opt-outs on the back of the shirt, rendering the effect of back touch zone location on touchee opt-outs not significant. In the front, opt-outs only occurred for two touch zones: the left and right upper chest area. These opt-outs only occurred when females were wearing the shirt.

6.0.3 Toucher Opt-Outs

Figure 6.2 shows the number of opt-outs from touchers per touch zone.

In total there were 24 touchers (12 females and 12 males) involved in the study. The front right upper chest received a total of 1 opt-out of the 24 possible opt-out opportunities (the opt-outs occurred 1/24 of the time). The front left upper chest received a total of 2 opt-outs of the 24 possible opt-out opportunities (the opt-outs occurred 1/12 of the time). The back right lower back received 1 opt-out of the 24 possible opt-outs (the opt-outs occurred 1/24 of the time).

We found a significant effect of touch zone location on opt-outs on the front of the shirt (Cochran's Q(3)=9.0, $p<0.05$). While one opt-out occurred on one of the lower back touch zones, we found no significant effect of back touch zone location on toucher opt-outs (Cochran's Q(3)=3.0, n.s.). In the front, opt-outs again only occurred for two touch zones: the left and right upper chest area. These opt-outs again only occurred when females were wearing the shirt. Differences between toucher and touchee opt-outs were not significant for any of the zones (Kruskal-Wallis H(1)=1.0, n.s.).

6.0.4 Effects of Gender on Opt-outs

To evaluate the effect of gender on opt-outs, we used one-tailed χ^2 tests of independence between male and female groups. Given that only the front upper chest received opt-outs, we tested the effect of gender only in this area, concatenating results for the left and right touch zones. We found a significant effect of gender of the touchee on opt-outs for the front upper chest area ($\chi^2(1)=3.99$, $p<0.05$). We did not find a significant effect of gender of the toucher on opt-outs for the front upper chest area ($\chi^2(1)=0.36$, n.s.), and also not for the lower back ($\chi^2(1)=1.02$, n.s.). We found no significant effects of pair composition (male-female, female-male, or same gender) on opt-outs for the front upper chest, for touchers ($\chi^2(1)=0.745$, n.s.) or touchees ($\chi^2(1)=0.243$, n.s.).

6.0.5 Observations on Opt-Outs

In one situation, the female toucher opted out for the front left upper chest (which was touched first) but did not opt-out for the front right upper chest (touched second). In that session, she rated the front right upper chest with a low 2 on the scale of comfort. In another situation, the male toucher opted out for the front left upper chest (which was also touched first). The female touchee in this session would not have opted out for this touch zone - however, later in the session, the female touchee opted out of the front right upper chest (the male toucher opted out of this touch zone as well). During this front right upper chest opt-out, it appeared that they were making a silent negotiation with each other regarding the opt-out. For the opt-out at the back right lower back, the male toucher opted out of this region after he had already touched the left lower back. He stated in his questionnaire, “the area felt too soft.” In all the opt-outs except one, the corresponding partners would have performed the touch task at the opted-out touch zones if their partners did not choose to opt-out.

6.0.6 Opt-outs from Participant Recruitment Pre-Screening

There was a total of 5 individuals who inquired about the study but chose not to take part in it after being informed about the details of the experiment. Of these 5 individuals, 4 were male and 1 was female. The female indicated that she was not comfortable taking part in the study. Three of the males also indicated that they were not comfortable with the touch tasks involved in the study. Among these three males, one of them, a graduate student who teaches courses at the university, stated his concern that the may be paired up with an individual who he might end up teaching in the future. He stated that regardless of the other participant's feelings when the task is being performed, they may later feel badly about it afterward. He thought that there is a high possibility of this occurring and that the touch tasks could lead to awkward future relationships for both the participants. Although he was not opposed to any of the interactions involved in the study, he was uncertain of the consequences that may result from the study. The fourth male who did not take part in the study after inquiring about it stated that he the monetary incentive was not enough for him.

6.1 Comfort Ratings

Figures 6.3 and 6.4 show the results for the minimum, median, and maximum comfort ratings by touchees and touchers, per touch zone location, as conveyed in the questionnaire. Comfort ratings for opt-outs were classified as 0 ratings, but note that

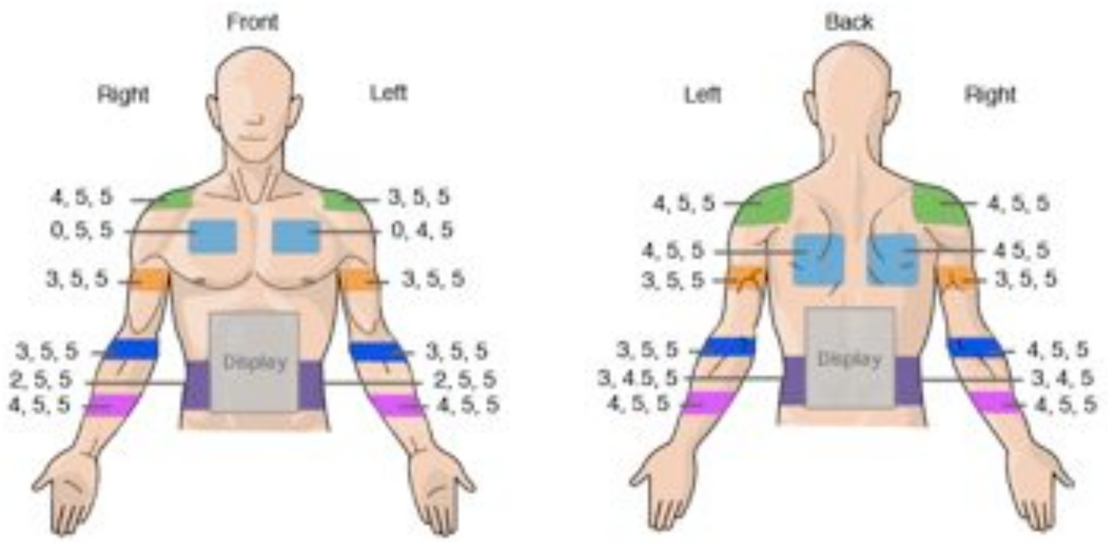

Figure 6.3: (Minimum, Median, Maximum) Comfort Ratings by *touchees* for each corresponding touch zone

classifying them as 1 ratings produced the same result. All the touch zones for both the touchees and touchers received maximum comfort ratings of 5 (out of 5) and high median comfort ratings of 4 and above.

6.1.1 Touchee Comfort Ratings

Figure 6.3 shows the minimum, median, and maximum comfort ratings by touchees per touch zone.

For the *touchees*, the front abdomen areas and the upper chest areas received the lowest minimum comfort ratings. The upper chest areas received opt-outs (as indicated by the zeros) but the lowest comfort rating given to the upper chest area when a participant did not opt-out was 2. Similarly, the front abdomen areas received low minimum comfort ratings of 2. The upper arm areas (on both the front and the back), elbow areas (except the back right elbow area), and the lower back areas

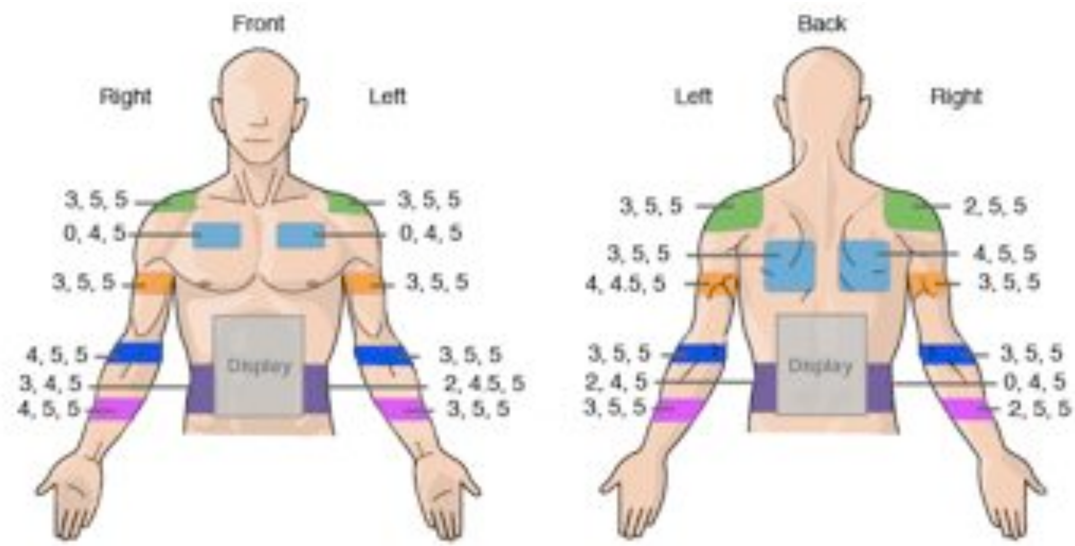

Figure 6.4: (Minimum, Median, Maximum) Comfort Ratings by *touchers* for each corresponding touch zone

received medium minimum comfort ratings of 3. The rest of the touch zones received high minimum comfort ratings of 4.

We found a significant effect of touch zone location on comfort ratings for the front of the shirt (Friedman's $\chi^2(11)=49.69$, $p<0.01$). We also found a significant effect of touch zone location on comfort ratings on the back of the shirt ($\chi^2(11)=47.13$, $p<0.01$).

Since there is no obvious test for pairwise comparisons in related non-parametric data, we performed two two-tailed Wilcoxon signed-ranked tests on the apparent outliers, upper chest and lower abdomen on the front, and one on the lower back data, against the average comfort ratings for the remaining touch zones on the respective side of the shirt, again averaging left and right zones. P-values were Bonferroni-corrected for the front of the shirt to account for multiple draws. We found a significant difference between the upper chest zone and the average of the other touch zones on the front of the shirt (including lower abdomen) (Z=-2.99, $p<0.01$). We found a significant difference between the lower abdomen zones and the average of the other touch zones on the front of the shirt (including upper chest) (Z=-2.33, $p<0.05$). We also found a significant difference between the lower back zones and the average of the other touch zones on the back of the shirt (Z=-2.91, $p<0.01$).

6.1.2 Toucher Comfort Ratings

Figure 6.4 shows the minimum, median, and maximum comfort ratings by touchers per touch zone.

For the *touchers*, the upper chest areas and right lower back areas received opt-outs, as well as the lowest minimum comfort ratings of 2 for participants that did not opt-out of this touch task. The back right shoulder, back right lower arm, back left lower back, and front left abdomen touch zones received low minimum comfort ratings of 2. The front shoulders, front upper arms, front left elbow area, front right abdomen, and front left lower arm touch zones received medium minimum comfort ratings of 3. On the back, the left shoulder, left upper back, right upper arm, elbow areas, and left lower arm touch zones also received medium minimum comfort ratings of 3. The rest of the touch zones received high minimum comfort ratings of 4.

We found a significant effect of touch zone location on comfort ratings for the front of the shirt (Friedmans $\chi^2(11)=41.80$, $p<0.01$). We also found a significant effect of touch zone location on comfort ratings on the back of the shirt (Friedmans $\chi^2(11)=41.15$, $p<0.01$).

To perform pairwise comparisons we followed the same procedure as for touchees. We found a significant difference between the upper chest zone and the average of the other touch zones on the front of the shirt (including the lower abdomen) ($Z=3.00$, $p<0.01$). Differences between the lower abdomen zones and the average of the other touch zones on the front of the shirt (including the upper chest) were not significant ($Z=1.66$, n.s.). We did find a significant difference between the lower back zones and the average of the other touch zones on the back of the shirt ($Z=-3.18$, $p<0.001$). Differences between toucher and touchee comfort ratings were significant for the back lower arm (Kruskal-Wallis $H(1)=5.16$, $p<0.05$), back shoulder ($H(1)=5.68$, $p<0.05$), upper back ($H(1)=4.37$, $p<0.05$) and front lower arm ($H(1)=4.48$, $p<0.05$) only.

6.1.3 Effects of Gender on Comfort Ratings

To evaluate the effect of gender on comfort ratings, we used one-tailed Mann-Whitney U tests between male and female groups. We only evaluated the front upper chest area, concatenating results for the left and right touch zones. For the front upper chest area, we found no significant effect of gender of the touchees ($U(1)=37.5$, n.s.), nor of gender of the touchers ($U(1)=37.0$, n.s.). We found no significant effect of pair composition (male-female, female-male, or same gender) on comfort ratings in the front or back of the shirt, except when the toucher was a female: with a significant effect of pair composition on comfort ratings for the upper chest ($U(1)=37.0$, $p<0.05$), front abdomen ($U(1)=35.0$, $p<0.05$), and lower back ($U(1)=28.0$, $p<0.05$).

6.1.4 Observations on Front vs. Back Touching

From the comments in the questionnaires, there were mixed feelings regarding whether it was more comfortable for the toucher to perform the touch tasks on the front of the shirt than on the back. Some touchers stated that the “back was more comfortable to touch because it felt more impersonal". However, some touchers stated the opposite that touching the front was more comfortable because they could make eye contact with the touchee and felt more comfortable approaching their interaction partner when they could see them. Similarly, there were also mixed feelings for the touchees regarding whether they felt more comfortable being touched on the front. A female touchee commented that because she could not see what the male toucher was doing, she rated all the back touch zones a 4 (agree) on the Likert Scale regarding comfort; she rated all the front touch zones a 5 (strongly agree). Furthermore, in another session, a male touchee stated that it was hard to anticipate when a touch would be made, thus making the back less comfortable to touch than the front; this participant, however, rated all touch zones with a 5 (strongly agree). A male and a female touchee both reported that when touched on the back, they "lost their balance as they could not anticipate touches". In contrast, another male touchee stated that "back touching was more comfortable because that area was less sensitive than the front". Several participants mentioned the association of touch in this study with massage therapy. For example, a female touchee stated that she "was used to getting massages, so touches that occurred felt good" (on both her right and left upper back areas).

6.1.5 Observations on the Tickle Factor

Several touchees (both male and female) reported that when they were touched at certain touch zones, they felt tickled. These touch zones include the upper arms (both front and back), lower back, and upper back.

6.1.6 Observations on Right vs. Left Touch Zones

A female touchee reported that she felt more comfortable being touched on her right side than on her left side. She also noted that "when her male toucher had to reach across her body to access a touch zone, she felt like it was a less friendly gesture." Two touchers who had to reach across their touchees to access touch zones also stated that "this made them feel awkward".

6.1.7 Observations on Specific Touch Zones

Both a female toucher and a female touchee stated in her questionnaires that areas with softer body tissue were more uncomfortable to touch. Both these participants also reported that "more solid areas (such as the elbow, lower arm, and shoulder areas) were more comfortable for touch". A female and a male toucher noted that the "higher the touch zone is, the easier it was for them to access". In general, participants stated that the shoulder and upper arm are natural, friendly, and optimal locations to place touch sensors. Also, several female touchees noted that the upper chest and lower back sensors were too close to private areas of the body.

6.1.8 Other Observations

During one of the trials in which a male was performing the touch tasks on a female wearing the interactive shirt, the experimenter noticed that the male toucher displayed physiological signs of nervousness. This was particularly prominent when the male was asked to locate the target image on the female's upper chest. During this touch task, the male toucher appeared to blink more often and his mouth gestures suggested that his mouth was dry. At the end of the session involving this male toucher and female touchee, they commented that in some cultures, they would already be married based on the touch interactions involved in the experiment.

In another session also involving a male toucher and female touchee, the female wrote in her questionnaire that when the male toucher performed the touch task on her front lower abdomen areas, she felt like he was grabbing her without permission – which made her feel uncomfortable.

Furthermore, one female toucher (who was paired with a female touchee) noted in her questionnaire that for the front abdomen and lower back areas, she felt more comfortable performing the same touch task the second time (on the opposite side of the body). For example, she touched the right abdomen first and when she touched the left abdomen later in the session, she felt more comfortable. This, however, was not reflected in her questionnaire in the comfort rating, as she rating these areas the same on both the left and right sides of the body.

During the pilot study, the experimenter did not instruct the toucher how to press on the shirt touch sensors. The toucher interacted with the touch sensors by using one finger and the touchee commented that using one finger felt like he was being poked/point at (and was thus felt slightly offended). As a result, for the actual study, the toucher was instructed to press on the touch sensors with even pressure using his or her index, middle, and ring fingers.

Lastly, as the shirts fitted individuals differently due to differing body shapes and sizes, it is worth noting that for petite size females who wore the smallest interactive shirt available (in a uni-sex size medium), the touch sensors were closer to their actual breast area than females who wore the shirt and were less petite in size.

6.2 Heart Rate

The raw heart rate data was filtered for noise; heart rate values below 40 and above 170 bpm were removed from the data sets.

A baseline was established at the beginning of each session before any touching started. This baseline was calculated using heart rate values from a 20 second interval taken 60 seconds before the first touch occurred. An average of the heart rate values was calculated for each touch zone. This average was calculated using the heart rate values recorded from when the touch started to when the touch ended. The heart rate was not recorded when a participant chose to opt out of the task. The average change in heart rate was calculated by subtracting the baseline from the average heart rate for each touch zone.

Figures 6.5 to 6.8 show the average change in the heart rate (bpm) for each touch zone when a female was touched by a female (Figure 6.5), a female was touched by a male (Figure 6.6), a male was touched by a female (Figure 6.7), and when a male was touched by a male (Figure 6.8). In each of these four graphs, the corresponding touch zones are:

1	Back Left Elbow Area	13	Front Left Abdomen
2	Back Left Lower Arm	14	Front Left Elbow Area
3	Back Left Lower Back	15	Front Left Lower Arm
4	Back Left Shoulder	16	Front Left Shoulder
5	Back Left Upper Arm	17	Front Left Upper Arm
6	Back Left Upper Back	18	Front Left Upper Chest
7	Back Right Elbow Area	19	Front Right Abdomen
8	Back Right Lower Arm	20	Front Right Elbow Area
9	Back Right Lower Back	21	Front Right Lower Arm
10	Back Right Shoulder	22	Front Right Shoulder
11	Back Right Upper Arm	23	Front Right Upper Arm
12	Back Right Upper Back	24	Front Right Upper Chest

Heart rates during touch events were significantly lower on the front than at the back of the shirt ($F(1,15)=6.1$, $p<0.05$). In the front, a single planned comparison showed a significantly lower heart rate for the upper chest area than the combined arm areas ($t(20)=-2.3$, $p<0.05$, two-tailed).

6.2.1 Observations on Heart Rate

During a trial which involved a female touchee and a male toucher, we noticed that the female touchee's heart rate increased before the actual touch task occurred (e.g. when the touchee was told that the toucher can proceed with the task). However, we noticed that the female's heart rate decreased once the toucher actually touched her.

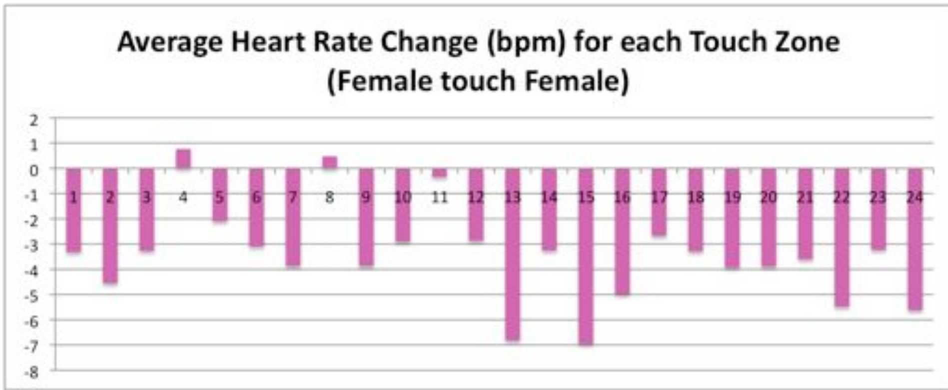

Figure 6.5: Average Heart Rate Change (bpm) for each Touch Zone (Female touching Female)

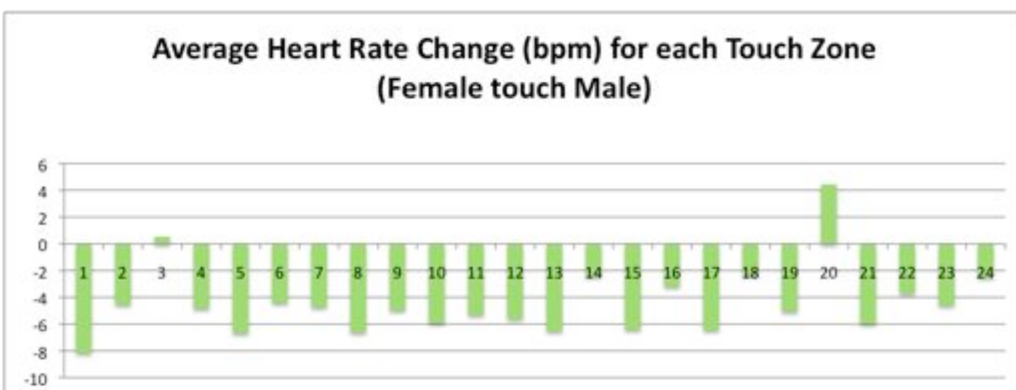

Figure 6.6: Average Heart Rate Change (bpm) for each Touch Zone (Female touching Male)

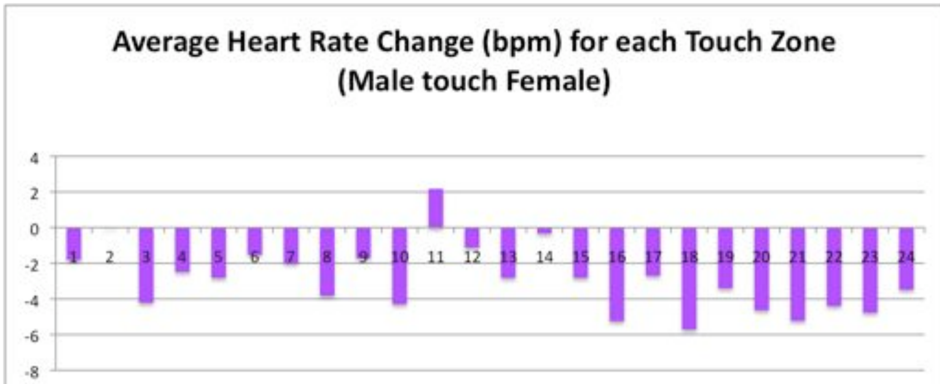

Figure 6.7: Average Heart Rate Change (bpm) for each Touch Zone (Male touching Female)

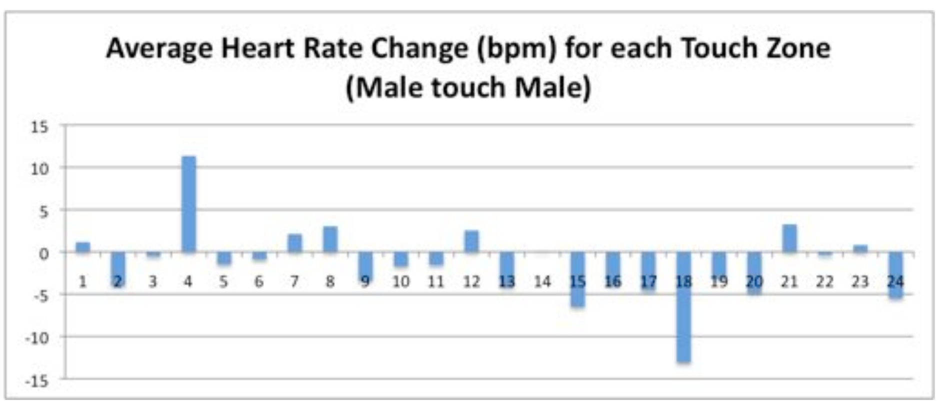

Figure 6.8: Average Heart Rate Change (bpm) for each Touch Zone (Male touching Male)

Chapter 7

Discussion

Our hypotheses were largely confirmed. We found significant differences in opt-outs between touch zones, on the front of the shirt, regardless of whether the participant was a toucher or touchee. Although we did find one male opting out of touching another male on the lower back, differences for opt-outs were not significant between back touch zones. Opt-outs in the front only occurred if the wearer was a female and only in the upper chest area. This is not a surprising finding as this zone is considered private within the culture of study [45]. We observed at least one instance in which the opt-out decision by one member of the pair influenced the opt-out decision of the other person, presumably to avoid embarrassment for the other person. As such, it appeared that comfort ratings were less socially disruptive than opt-outs in the interaction between participants, as they could be provided in private.

7.0.2 Comfort Ratings

Findings for comfort ratings were more sensitive to nuances in social touch experience, and again largely confirmed our hypotheses. We found significant differences between touch zones not just on the front, but, somewhat surprisingly, also on the back of the shirt. On the front, the upper chest and lower abdominal zones were the clear outliers in comfort ratings. We believe the lower abdominal regions were considered more private due to the privacy of the areas right below these regions. Furthermore, according to Hutchinson et al. [25] and Jourard [26], the abdomen region is the least frequently used body part in physical contact, even amongst friends. On the back, the lower back region was the outlier. Participants' comments appeared to indicate hygienic motives for its low rating, but we do not rule out that the privacy of the body part right below this area had an effect. Although we found some significant but small differences between touchers and touchees for a selection of locations, comments suggest that these were due to a differential assessment of the physical awkwardness of touching in those locations. Somewhat surprisingly, we also found no gender differences in overall comfort ratings. While from opt-outs scores it is apparent that the upper chest areas are considerably more private for female than for male touchees, our findings are in line with Jourard's observations that males generally consider their upper chest as a private as well. This may also explain our one significant finding in terms of gender pairing: female touchers rated touching a male touchee in less comfortable zones considerably higher than male touchers.

7.0.3 Heart Rate

Figure 7.1 shows areas to be avoided and embraced for touch sensor placement. Overall, heart rates appeared lower for red zones in Figure 7.1 than for green zones, a finding that was confirmed between front upper chest (uncomfortable) and front arm (comfortable) zones. This suggests that social touch in less comfortable touch zones has a greater calming effect. We believe that heart rates were significantly lower in

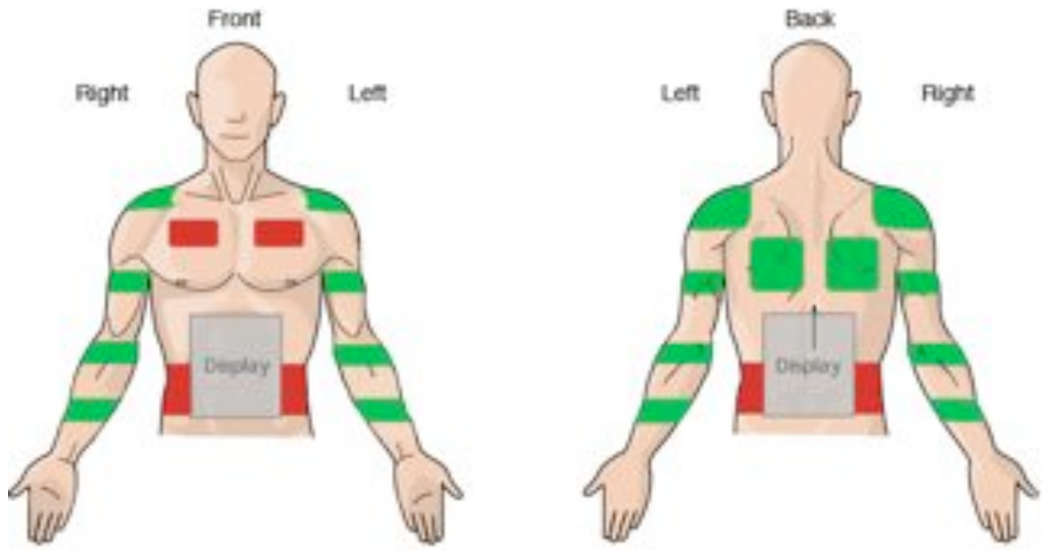

Figure 7.1: Appropriate (green) and inappropriate (red) areas for touch sensor placement.

the front because it included the most uncomfortable area: the upper chest. Our results are consistent with Drescher et al.'s findings [18]. In their experiment, heart rate deceleration was not influenced by the sex of the experimenter nor by participant's expectations of the touch. Instead, they suggested that a cardiac deceleration response to touch is a congenital reflex that originates in maternal bonding processes. In our study, the extent of deceleration does appear to be influenced by the comfort rating of the touch zone

7.0.4 Design Recommendations

Our study provides some clear guidelines as to the social appropriateness of the placement of touch sensors on interactive e-textile clothing. As for inappropriate placements, perhaps the most interesting finding is that the upper frontal chest area should not just be avoided in females, but also in males. From a technical point of view, placement of sensors right next to the display in the lower frontal abdominal region would have been ideal. However, results strongly suggest this area should be avoided for touch sensors. The same holds for sensor placement right next to the display on the lower back, which should be avoided as well. The most appropriate areas for sensor placement, then, are on the arms and shoulders, as indicated in Figure 7.1 by the green zones, as well as the upper back. We modified our interactive Lumalive shirt design to incorporate these findings.

7.1 Limitations of Our Findings

We should note that the study presented in this thesis did not vary the placement of the display apart from front to back. Our results therefore do not extend to, and may be influenced by, display placement. Additionally, we did not investigate the placement of touch sensors on the display itself. As the Lumalive display resembles a thin and lightweight pillow, the placement of touch sensors on the display directly could potentially produce different results in comfort ratings for both the touchers and touchees. During our study, touchees wore a shirt that was meant to feel like a second skin (e.g. the shirt was supposed to be skin-tight). This allowed us to test touch interactions that mimicked a toucher touching a touchee's skin. If touch sensors were placed directly on the Lumalive display, the toucher would not feel as though he or she is directly touching the touchee's body. As we wanted to maintain consistency among all touch zones and not obstruct the display, we did not place any touch sensors on the flexible display. We do, however, envision that touchers may feel more comfortable touching a display as opposed to directly touching the touchee's body. Similarly, it is likely that the touchee may feel more comfortable being touched on touch sensor with padding. These results would need to be confirmed in a future study.

We should also note that our recommendations are with regards to some generic application of e-textile garments, and do not generalize to, for example, artistic applications. In fact, the context and environment that the touch interactions take place in may vary the results that were reported in this thesis. We conducted our study in a laboratory setting in which only the toucher, touchee, experimenter and experiment assistant were present. As the main task in the study involved touching, the participants may have felt more inclined to touch someone or be touched by someone than if they were in a different setting (e.g. people would be less inclined to touch someone or feel comfortable being touch by someone in an office workplace). Additionally, the presence of others may affect comfort ratings and whether participants would opt-out of certain touch tasks. For example, if the participant's parents or significant others were present in the room, the participants may feel less comfortable with the touch tasks. The presence of friends may also be a factor affecting opt-outs and comfort ratings for participants – for example, a participant may feel pressured by friends to perform or not perform a touch task.

Our research is also limited by being conducted within the context of a largely non-contact culture [39]. Although our participants came from many cultural backgrounds, the experiment was restricted to Canada only. Also our results may have been different had participants not been strangers. Strangers were chosen to maintain consistency among the touchee and toucher relationships.

Our results are furthermore limited by the fact that the sample was largely based on a student population - meaning results could be different for different age groups.

Chapter 8

TagURIt: A Proximity-based Game of Tag Using Lumalive e-Textile Displays

This chapter serves as an application of the work presented in the previous chapters.

8.1 TagURIt, An Application for Interactive E-Textile Displays

We present an electronic game of tag that uses proximity sensing and Lumalive displays on garments. In our game of tag, each player physically represents a location-tagged Universal Resource Indicator (URI). The URIs, one chaser and two target players, wear touch-sensitive Lumalive display shirts. The goal of the game is for the chaser to capture a token displayed on one of the Lumalive shirts, by pressing a touch sensor located on the shirt. When the chaser is in close proximity to the token player, the token jumps to the shirt of the second closest player, making this children's game more challenging for adult players. Our system demonstrates the use of interactive e-textile displays to remove the technological barrier between contact and proximity in the real world, and the seamless representation of gaming information from the virtual world in the real world.

8.2 Introduction

E-textiles potentially provide a great medium for social interactions in a public setting. Wearable computing provides a platform for conveying emotions, exchanging information, displaying information, and for role-playing games. With this in mind, we developed a game of tag to demonstrate the use of wearable computing for displaying and exchanging information in a social environment. In this chapter, we present TagURIt, a dynamical game of tag in which players physically represent a Universal Resource Indicator tagged with real-time location information (see Figure 8.1). Each player in this game wears a high resolution Lumalive textile display embedded in a shirt. The display is powered by a small wearable Bluetooth Arduino computer that has a number of sensors allowing the TagURIt system to track how close the player is to a chaser (the person who is "it"), as well as when the player is touched by the chaser. At the beginning of the game, one player is randomly chosen as the chaser by the system, while the others are designated targets. As the TagURIt system keeps track of the relative distances between chaser and the target URIs, it displays a tag token on the Lumalive display of the target that is second closest to the chaser. When the chaser comes closest to this target player, the token jumps to the Lumalive display on the shirt of the now second closest player, making this a much more challenging game for the chaser. Tag tokens have different points associated with them, which vary through time. TagURIt thus augments the traditional game of tag with new strategies that more realistically represent a manhunt scenario, making for a more interesting game for adults to play in social settings.

Figure 8.1: Participants playing the TagURIt game

8.3 Social Gaming

People enjoy playing multi-user games because it is a social activity that is shared by a group of individuals. Engaging in a social game is an exciting opportunity to get to know other people because it is free from the usual cognitive barriers that prevent us both from approaching people and from unveiling ourselves in a non-game environment [37].

While the introduction of online social gaming has allowed users to play against one another without being limited by their geographical location, natural interactions such as behavioral engagement, proximity and touch are not preserved over networks. In recent years, physical proximity-based games have emerged that make use of some correlate between player location in the real world, as tracked by a cellular phone, and the virtual game world [14] [17] [20] [30] [29] [41]. For example, Falk [20] studies playful misconduct in social games, by allowing cellular phone owners to tag surrounding owners. In Pirates! [20], users use PDAs to explore their physical environment to fulfill their missions and interact with other players. Pirates! uses proximity sensing and a projection of the game world onto the physical world to conserve the social interaction. Another approach to social gaming is using a more immersive environment where people interact only in a 3D virtual world, e.g., in the MIND-WARPING gaming system [41]. However, none of these games incorporate displays directly integrated into the world of the players, making the virtual game play disjoint from the physical game play, be it on a mobile phone or on semi-immersive screens.

Human Pacman [16] was one of the first games to allow for physical contact in the real world to represent represents virtual contact in the game world. It also directly integrated display into the users environment. In this game, humans physically role-played the characters of the Pacman and Ghosts. During game play, the Pacman player devoured the virtual target by tapping on the physical targets shoulder. Also, to obtain a virtual magic cookie, the Pacman player had to physically pick up a treasure box with an embedded Bluetooth device. To allow the real and virtual worlds to fuse, however, the Human Pacman system required an augmented reality goggle to be worn by the chaser. We were interested in exploring how we could remove the technological barrier between contact and proximity in the real world, and the seamless representation of gaming information from the virtual world in that real world, through the use of e-textile displays.

Although considerable work has been done in the area of wearable computing, currently there are no interactive garments available that allow for a display of sufficient resolution to display symbolic or graphic information at any level of realism within a game. Additionally, current high-resolution electronic garments are unable to detect and respond to its proximity to another electronic garment.

8.4 TagURIt: A Proximity Based Tag Game with Lumalive Displays

In order to address both the issue of merging virtual and physical game worlds, and developing more interactivity into wearable e-textile displays, we developed an electronic version the game of Tag. Tag is chasing other players in an attempt to tag or touch them (usually with their hands).

In our modified version of the game of tag, a chaser (the player who is it), is required to obtain a token from one of the two individuals (players) who are wearing interactive and proximity sensing Lumalive shirts (see Figure 8.1). In order to obtain one of the tokens (see Figure 8.2 for an example of a token), the chaser needs to press on one of the touch sensors (also is displayed on his/her shirt). The token can jump back and forth between the two players based on the proximity of the player to the chaser - that is, when the chaser gets closest to the target player (who has the token displayed on her shirt), this token will jump to a player who is the next furthest away from the chaser.

The game ends when the chaser touches one of the touch sensors on the player with the token. Two different Super Mario Brothers themed tokens can be captured: a goomba and a boo (Figure 8.2). We programmed the boo to appear less frequently than the goomba on the Lumalive display of a target. Obtaining the boo results in

Figure 8.2: The goomba token and the boo token

20 bonus points for the chaser, 10 for the target while obtaining the goomba results in 10 bonus points for the chaser, and 20 for the target.

Additionally, as an incentive for the target players to try to hold onto their token longer (that is, to prevent it from jumping to the other player in the game), the longer the target player holds onto the token, the more points he/she accumulates for him/herself. The targets score is incremented by 1 point for each second he/she has possession of the token. The inverse happens for the chaser: he/she starts out with 150 points, with one point subtracted for every two seconds. While targets can theoretically collect 300 points in a 5 minute game, the token is likely to distribute these points evenly between two targets, putting each at an average of 150 points after 5 minutes.

Depending on which touch sensor is pressed to obtain the token, the chaser may receive a bonus multiplier to allow him/her to achieve a 300 point score as well. If the chaser presses on one of the shoulder touch sensors to capture the token, the chaser receives no bonus. Since the lower arm touch sensor is harder to reach (as the players can protect that area), pressing on an arm touch sensor allows the chaser to receive a 2x multiplication of his/her points. Each game lasts for 5 minutes, or until the chaser captures a token, whichever comes first.

8.5 Touch Sensing

In our implementation of an interactive Lumalive shirt, we used conductive fabric (pure copper polyester taffeta) patches to create soft touch sensors (see Figure 8.3). To make these soft sensors, we used two layers of conductive fabric that are slightly separated from each other. When pressure is applied to the top conductive fabric layer, the circuit is closed, allowing electricity to flow. The touch sensors were wired to a Lilypad Arduino using mini alligator prototyping clips. The touch sensors were placed on the shoulders and lower arm areas since the results from Chapter 7 suggest that these regions are most appropriate for sensor placement. A touch press prompts the Lilypad Xbee to send a signal to the Philips Lumalive control unit for a Game Over.

8.6 Location Tracking

We developed a radio frequency (RF) received signal strength (RSSI) based solution that allows tracking of relative distances between all of the players. This was done using Lilypad XBees that are connected to the Lilypad Arduinos (see Figure 8.4). Each Lilypad XBee measures the signal strength to the other Lilypad XBees. When the chaser approaches a target player (and if their RSSI value crosses a predetermined threshold value), the Lilypad Arduino will send a signal to the Lumalive remote control. This causes what is shown on the target players' Lumalive screen to change.

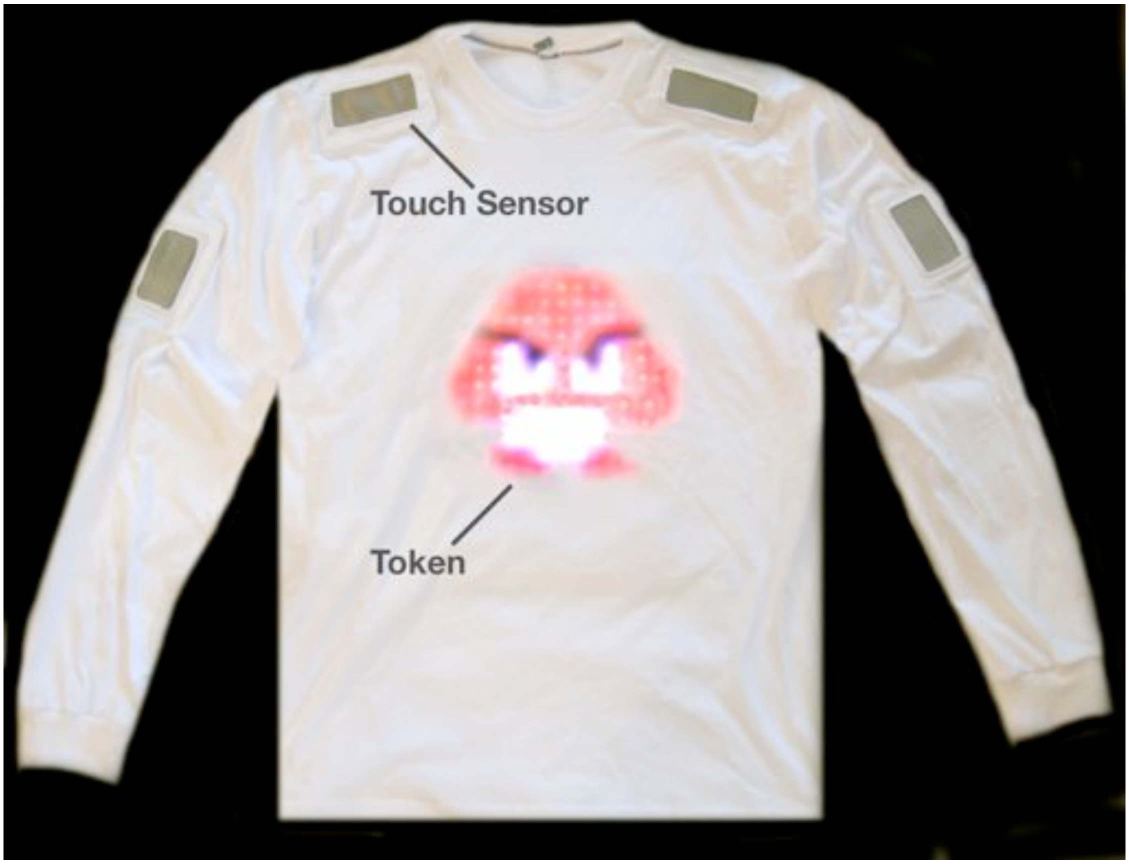

Figure 8.3: Interactive Lumalive Shirt with Touch Sensors (Front)

For a complete of the system architecture for TagURIt, please refer to Figure 8.5.

8.7 Evaluation

To evaluate TagURIt, we held a hands-on demonstration of the system at the 2011 ACM Conference on Human Factors in Computing Systems (CHI). The demonstrator wore the chaser shirt and the target player shirts were fitted on mannequins. This allowed us to demonstrate the proximity and touch capabilities of the shirts. We received positive feedback regarding our system and our game. Participants mentioned that it was an interesting application to wearable computing and were interested in

Figure 8.4: Interactive Lumalive Shirt with Touch Sensors (Back)

whether or not we created the display ourselves. Since we used the Lumalive display in our implementation of TagURIt, participants also wondered how much it would cost to develop our system. To create a full implementation of TagURIt with 3 shirts in total (2 target player shirts and 1 chaser shirt), it would cost approximately $6000. Other participants asked about the available applications to the technology used in TagURIt and we explained that in the near future, we anticipate that interactive garments will become as popular as smartphones. As such, TagURIt is an early prototype of an example of interactive garments. Though TagURIt is focused primarily on a game, the technology used in the system can be used in a variety of applications

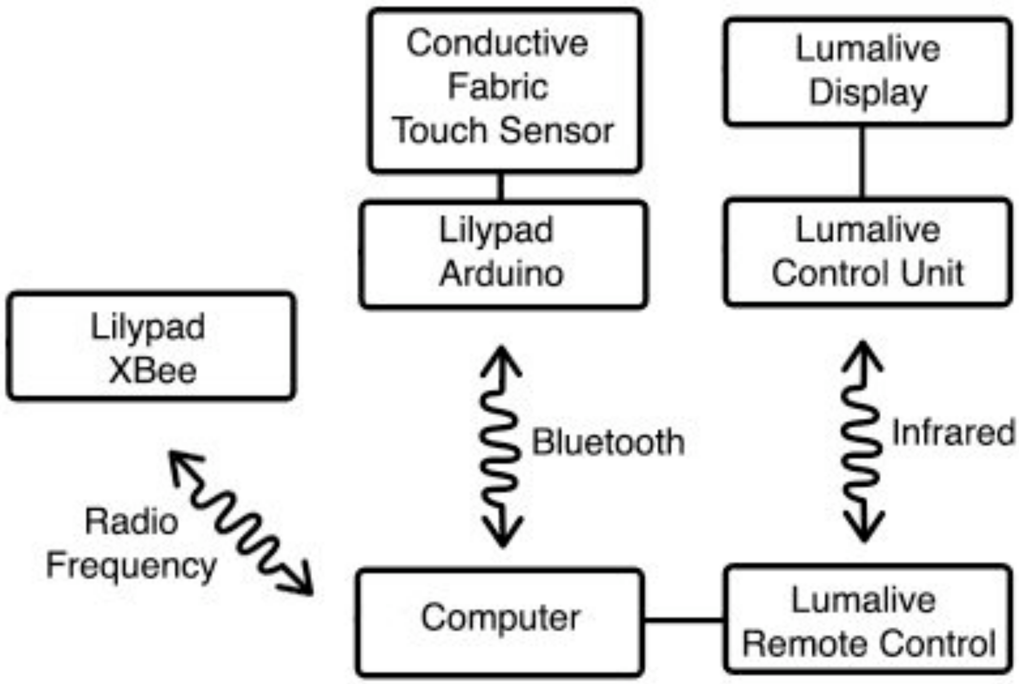

Figure 8.5: System Architecture of TagURIt

such as other games, entertainment, location-tracking of individuals (e.g. finding a friend based on the color or directions on your shirt), and social networking (e.g. when you get close to another person at a conference and shake his/her hand, contact information is exchanged, displayed, and stored in the smart garment). Lastly, participants also commented that they think that children in particular would be interested in this sort of system.

From the feedback received at CHI, we learned that there is a potential market for interactive garments, particularly for children. Perhaps it would be best to create games involving interactive garments focused on young children. This would first require the cost of the system to decrease, which we anticipate will occur in the near future, as flexible high-resolution displays and other required technology used in the TagURIt shirts become more readily available in the consumer market. Games like TagURIt would require a plug-and-play interface to allow users of all ages to be able to setup their game easily. Also, the shirts used in TagURIt would need to be created more robust (especially if children are going to be wearing them), as we restricted participants from actually wearing the shirts, due to the delicate nature of the prototypes. From the positive feedback of TagURIt, we also confirmed that individuals have a general interest in wearable computing and that they would actually be interested in playing the game. This provides confirmation that individuals would be comfortable being touched on their shoulders and lower arm areas in a gaming scenario.

8.8 Summary

In this chapter, we presented an implementation of an interactive Lumalive shirt that allows for proximity sensing. This technology was demonstrated using a modified game of tag in which the goal of the game is for the person who is it (the chaser) to capture a token. The token is obtained by pressing on a touch sensor of the player who has the token displayed on his/her shirt. Our proximity-based game of tag with Lumalive displays is social activity that is built on mobility, physical actions, and the real world as a playground. While this game only lists one chaser and two additional players, the game can be expanded to include more chasers and players for a more immersive and engaging experience. We believe that our game of tag is a novel experience in the new hybrid field of physical, social, mobile gaming, and e-textiles that is built on ubiquitous computing and networking technology.

Chapter 9

Conclusions

9.1 Future Work

Based on the limitations of our study (Chapter 7), future research would need to be conducted to further investigate the placement of touch sensors on e-textile garments. As the display was only placed on the touchee's front abodmen and lower back in our study, the location of the display could potentially alter the results found in our study. Also, touch sensors were not placed directly on the display; placing touch sensors directly on the display could also affect comfort ratings and the frequency of opt-outs. As such, future studies should be conducted to test the location of the display and the placement of touch sensors on the Lumalive directly.

As the study was conducted in a laboratory setting, it would be worthwhile to perform this same experiment in different environments (such as an office workplace, nightclub/bar, home, etc). Furthermore, the study was conducted with only the toucher, touchee, experimenter, and experiment assistant present. Future studies could investigate whether the presence of others (strangers, significant others, family members, friends, colleagues, etc) would affect comfort ratings and the frequency of opt-outs.

During this study, due to limitations of the hardware, we were only able to track the heart rate of the touchee. It would be beneficial to track the toucher's heart rate during the session in future experiments. It would also be interesting to analyze the heart rate of both the toucher and touchee during opt-outs, as this data was not used in the analysis of our study.

Since our study was limited to only individuals recruited from a university (aged 18-30), future work needs to be done to investigate whether conducting the study on individuals of different age groups would produce different results. From the evaluation of TagURIt, it is evident that children would be interested in wearing interactive shirts (e.g. for gaming purposes). Thus, it would be particularly useful to conduct this experiment on children. Furthermore, it would be beneficial to conduct this study on elderly individuals for the purpose of a medical interactive shirt.

Furthermore, while this study did involve individuals of varying cultural backgrounds, it was restricted to only Canadians. In order to create interactive shirts that would be used world-wide, it is important to investigate the placement of touch sensors on e-textiles garments in different countries. Future studies would need to be conducted in a manner that is sensitive to cultural differences in social touch behaviour.

9.2 Conclusions

In this thesis, we discussed the design of an e-textile shirt with an interactive Lumalive display featuring a touch-controlled image browser. To determine where to place touch sensors, we investigated which areas of the Lumalive shirt users would be comfortable touching or being touched. Results show significant differences in opt-outs between touch zones on the front of the shirt. For both touchers and touchees, opt-outs occurred mostly in the upper chest touch zones. We also found significant differences in comfort ratings between touch zones on the front areas, as well as on the back of the shirt. On the front, the upper chest and lower abdominal zones were the least comfortable touch zones. On the back, the lower back was the least comfortable touch zone. We found no gender effects on overall comfort ratings, suggesting the upper chest area, in particular, was equally uncomfortable to males as it was to females. Our physiological measures suggests that touching less comfortable areas has a significantly greater calming effect on heart rate than touching more comfortable areas. Overall, our results suggest that participants were less comfortable with touches on the upper chest, the lower abdomen, and the lower back. We conclude that the most appropriate areas for touch sensors on a shirt are on the arms and shoulders, as well as on the upper back.

Bibliography

[1] Chalayan, hussein. past collections. http://www.husseinchalayan.com/ [Last accessed: October, 2010].

[2] Cutecircuit. the galaxy dress. http://www.cutecircuit.com/products/galaxydress/ [Last accessed: February, 2011].

[3] Foursquare. http://www.foursquare.com/ [Last accessed: January, 2011].

[4] Phidgets, inc. capacitive touch sensor. http://www.phidgets.com/ [Last accessed October 2010].

[5] Philips lumalive. http://www.lumalive.philips.com/ [Last accessed October 2010].

[6] Polar. http://www.polarusa.com/ [Last accessed: October, 2010].

[7] Skin: Dresses. http:// www.design.philips.com/ [Last accessed: October, 2010].

[8] Sparkfun electronics. http://www.sparkfun.com/ [Last accessed October 2010].

[9] Kristina Andersen. It felt like clown sparkles. *interactions*, 11(5):61–63, 2004.

[10] Kristina Andersen and Joanna Berzowska. Worn technology - the alteration of social space. *Open 2006/No. 11: Hybrid Space*, 2006.

[11] J Berzowska. Electronic textiles: Wearable computers, reactive fashion, and soft computation. *Textile*, 3:219, 2005.

[12] J. Berzowska and M. Coelho. Memory-rich clothing. In *CHI '06: CHI '06 extended abstracts on Human factors in computing systems*, pages 275–278, New York, NY, USA, 2006. ACM.

[13] Joanna Berzowska and Marcelo Coelho. Kukkia and vilkas: Kinetic electronic garments. In *Proceedings. Ninth IEEE International Symposium on*, pages 82–85, 2005.

[14] S. Brewster, M. Dunlop, C Baber, and O Westmancott. Social networks and mobile games: The use of bluetooth for a multiplayer card game. In *Lecture Notes in Computer Science 3160*, pages 98–107. Springer Berlin, 2004.

[15] Leah Buechley, Mike Eisenberg, Jaime Catchen, and Ali Crockett. The lilypad arduino: using computational textiles to investigate engagement, aesthetics, and diversity in computer science education. In *CHI '08: Proceeding of the twenty-sixth annual SIGCHI conference on Human factors in computing systems*, pages 423–432, New York, NY, USA, 2008. ACM.

[16] Adrian David Cheok, Kok Hwee Goh, Wei Liu, Farzam Farbiz, Siew Wan Fong, Sze Lee Teo, Yu Li, and Xubo Yang. Human pacman: a mobile, wide-area entertainment system based on physical, social, and ubiquitous computing. *Personal Ubiquitous Comput.*, 8:71–81, May 2004.

[17] Josh Coe and Monchu Chen. Making friends by killing them: using location-based urban gaming to expand personal networks. In *Proceedings of the 28th of*

the international conference extended abstracts on Human factors in computing systems, CHI EA '10, pages 3553–3558, New York, NY, USA, 2010. ACM.

[18] V. Drescher, Horsley G., and W. Whitehead. Heart rate response to touch. *Psychosomatic Medicine*, 42:559–565, 1980.

[19] Anthony Dunne and William W. Gaver. The pillow: artist-designers in the digital age. In *CHI '97: CHI '97 extended abstracts on Human factors in computing systems*, pages 361–362, New York, NY, USA, 1997. ACM.

[20] Jennica Falk, Peter Ljungstrand, Staffan Björk, and Rebecca Hansson. Pirates: proximity-triggered interaction in a multi-player game. In *CHI '01 extended abstracts on Human factors in computing systems*, CHI '01, pages 119–120, New York, NY, USA, 2001. ACM.

[21] F. Gemperle, C. Kasabach, J. Stivoric, M. Bauer, and R. Martin. Design for wearability. In *Proceedings of the 2nd IEEE International Symposium on Wearable Computers*, ISWC '98, pages 116–, Washington, DC, USA, 1998. IEEE Computer Society.

[22] Antal Haans, Christiaan de Nood, and Wijnand A. IJsselsteijn. Investigating response similarities between real and mediated social touch: a first test. In *CHI '07: CHI '07 extended abstracts on Human factors in computing systems*, pages 2405–2410, New York, NY, USA, 2007. ACM.

[23] H.F. Harlow. The nature of love. *American Psychologist*, 13:673–685, 1958.

[24] Paul Holleis, Albrecht Schmidt, Susanna Paasovaara, Arto Puikkonen, and Jonna Häkkilä. Evaluating capacitive touch input on clothes. In *Proceedings of the 10th*

international conference on Human computer interaction with mobile devices and services, MobileHCI '08, pages 81–90, New York, NY, USA, 2008. ACM.

[25] K.L. Hutchinson and C.A Davidson. Body accessibility re-revisited: The 60s, 70s and 80s. *J.W. Neuliep (Ed.), Replication Research in the Social Sciences*, pages 329–340, 1991.

[26] S. M. Jourard. An exploratory study of body accessibility. *British Journal of Social and Clinical Psychology*, 5:221–231, 1966.

[27] Thorsten Karrer, Moritz Wittenhagen, Leonhard Lichtschlag, Florian Heller, and Jan Borchers. Pinstripe: eyes-free continuous input on interactive clothing. In *Proceedings of the 2011 annual conference on Human factors in computing systems*, CHI '11, pages 1313–1322, New York, NY, USA, 2011. ACM.

[28] Sunyoung Kim, Eric Paulos, and Mark D. Gross. Wearair: expressive t-shirts for air quality sensing. In *TEI '10: Proceedings of the fourth international conference on Tangible, embedded, and embodied interaction*, pages 295–296, New York, NY, USA, 2010. ACM.

[29] B. Kirman and C Linehan. Naughtiness and mischief in mobile play. In *Mobile-HCI'10*, 2010.

[30] C. Linehan, B. Kirman, S. Lawson, and M. Doughty. Blowtooth: Pervasive gaming in unique and challenging environments. In *Ext. Abstracts CHI10*, pages 2695–2705. ACM Press, 2010.

[31] Emily Lovell and Leah Buechley. An e-sewing tutorial for diy learning. In *IDC '10: Proceedings of the 9th International Conference on Interaction Design and Children*, pages 230–233, New York, NY, USA, 2010. ACM.

[32] C. McBride, M. G. King, and J. W. James. Social proximity effects on galvanic skin response in adult humans. *Journal of Psychology*, 61:153–157, 1965.

[33] Grace Ngai, Stephen C.F. Chan, Joey C.Y. Cheung, and Winnie W.Y. Lau. The teeboard: an education-friendly construction platform for e-textiles and wearable computing. In *CHI '09: Proceedings of the 27th international conference on Human factors in computing systems*, pages 249–258, New York, NY, USA, 2009. ACM.

[34] Grace Ngai, Stephen C.F. Chan, Vincent T.Y. Ng, Joey C.Y. Cheung, Sam S.S. Choy, Winnie W.Y. Lau, and Jason T.P. Tse. i*catch: a scalable plug-n-play wearable computing framework for novices and children. In *CHI '10: Proceedings of the 28th international conference on Human factors in computing systems*, pages 443–452, New York, NY, USA, 2010. ACM.

[35] Maggie Orth, Rehmi Post, and Emily Cooper. Fabric computing interfaces. In *CHI '98: CHI 98 conference summary on Human factors in computing systems*, pages 331–332, New York, NY, USA, 1998. ACM.

[36] J.E. Pattison. Effects of touch on self-exploration and therapeutic relationship. *J. Consult. Clin. Psycho*, 40:170–175, 1973.

[37] Eric Paulos. Mobile play: Texting, blogging, tagging, and messaging. In *Ubicomp03*, 2003.

[38] R.W. Picard. *Affective Computing*. 1997.

[39] M.S. Remland and T. S. Jones. Cultural and sex differences in touch avoidance. *Percep. Motor Skills*, 67:544–546, 1988.

[40] T. Schiphorst. Affectionate computing: Can we fall in love with a machine? *IEEE Multimedia*, 13:20–24, 2006.

[41] Thad Starner, Bastian Leibe, Brad Singletary, and Jarrell Pair. Mind-warping: towards creating a compelling collaborative augmented reality game. In *Proceedings of the 5th international conference on Intelligent user interfaces*, IUI '00, pages 256–259, New York, NY, USA, 2000. ACM.

[42] R Summerfield. A blank canvas for creativity. *Calgary, Herald*, March 13, 2007.

[43] N.M. Sussman and H.M. Rosenfeld. Touch, justification, and sex: Influences on the aversiveness of spatial violations. *Journal of Social Psychology*, 106:215–225, 1978.

[44] Stephen Thayer. History and strategies of research on social touch. *Journal of Nonverbal Behavior*, 10:12–28, 1986. 10.1007/BF00987202.

[45] M. Tomita. An exploratory study of touch zones in college students on two campuses. *Californian Journal of Health Promotion*, 6:1–22, 2008.

[46] F. Wilhelm, A. Kochar, W. Roth, and G. James. Social anxiety and response to touch: incongruence between self-evaluative and physiological reactions. *Biological Psychology*, 58:181–202, 2001.

[47] T. G. Zimmerman. Personal area networks: near-field intrabody communication. *IBM Syst. J.*, 35(3-4):609–617, 1996.

Appendix A

General Research Ethics Board Approval

July 3, 2009

Queen's University

OFFICE OF RESEARCH SERVICES
Dunning Hall, Room 113
Queens University
Kingston, Ontario, Canada
Tel 613 533-6081
Fax 613 533-6806
ors@queensu.ca
www.queensu.ca/vpr/

Sylvia Cheng
Master's Student
School of Computing
Queen's University

GREB Ref # GCISC-031-09
Title: "Hands ON – A Usability Study for Clothing Computers"

Dear Sylvia Cheng:

The General Research Ethics Board (GREB), by means of a delegated board review, has cleared your proposal entitled **"Hands ON – A Usability Study for Clothing Computers"** for ethical compliance with the Tri-Council Guidelines (TCPS) and Queen's ethics policies. In accordance with the Tri-Council Guidelines (article D.1.6) and Senate Terms of Reference (article G), your project has been cleared for one year. At the end of each year, the GREB will ask if your project has been completed and if not, what changes have occurred or will occur in the next year.

You are reminded of your obligation to advise the GREB of any adverse event(s) that occur during this one year period (see webpage: www.queensu.ca/vpr/greb/addforms.htm#Adverse). An adverse event includes, but is not limited to, a complaint, a change or unexpected event that alters the level of risk for the researcher or participants or situation that requires a substantial change in approach to a participant(s). You are also advised that any adverse events must be reported to the GREB within 48 hours.

You are also reminded that all changes that might affect human participants must be cleared by the GREB. For example you must report changes in study procedures or implementations of new aspects into the study procedures on the Ethics Change Form that can be found at http://www.queensu.ca/vpr/greb/addforms.htm#Change. These changes must be sent to Linda Frid at the Office of Research Services or FRIDL@queensu.ca prior to implementation. Ms. Frid will forward your request for protocol changes to the appropriate GREB reviewers and / or the GREB Chair.

On behalf of the General Research Ethics Board, I wish you continued success in your research.

Yours sincerely,

Joan Stevenson

Joan Stevenson, PhD
Professor and Chair
General Research Ethics Board

JS/lf

copies: Faculty Supervisor: Roel Vertegaal
Co-Applicant: Andreas Hollatz, Graduate Student
Admin Contact: Dean McKeown

Appendix B

Questionnaires

This section provides the questionnaires that were given to the participants in the study. The touchees completed the questionnaire titled ”Hands On: A Usability Study for Clothing Computers Questionnaire for Person Being Touched”. The touchers completed the questionnaire titled ”Hands On: A Usability Study for Clothing Computers Questionnaire for Person Performing the Touches”.

In every question in both of the questionnaires, the experimenter filled in the touch zone location on the blank line. For example, for the questionnaires completed by the touchees, question (1) would read: I felt comfortable being touched on the front left upper back (Circle a number below). This was necessary because the order of the touch zones were randomized before each experiment session.

Hands On: A Usability Study For Clothing Computers

Questionnaire for Person Being Touched

Subject:

Date: _________________ (DD/MM/YYYY)

Gender: M F

Gender of interaction partner (person who is touching you): M F

Sexual Orientation: _________________ I choose to not disclose this info

Would you consider your partner a stranger? Y N
If no, please indicate your relationship to this person:

Photo Finding Task

For the following questions, you will be asked to provide a number to rate how comfortable an experience felt for you. The rating scale is as follows:

1 = Strongly disagree
2 = Disagree
3 = Neutral
4 = Agree
5 = Strongly agree

If you or your partner chose to opt out of any task, circle N/A for the corresponding question.

For reference to the body parts, please refer to the body map provided to you.

---

1) I felt comfortable being touched on the ______________ (Circle a number below)

   Strongly disagree strongly agree
   1 2 3 4 5 N/A

   Please indicate why you felt comfortable or uncomfortable:

2) I felt comfortable being touched on the ______________ (Circle a number below)

Strongly disagree strongly agree
1 2 3 4 5 N/A

Please indicate why you felt comfortable or uncomfortable:

3) I felt comfortable being touched on the ______________ (Circle a number below)

Strongly disagree strongly agree
1 2 3 4 5 N/A

Please indicate why you felt comfortable or uncomfortable:

4) I felt comfortable being touched on the ______________ (Circle a number below)

Strongly disagree strongly agree
1 2 3 4 5 N/A

Please indicate why you felt comfortable or uncomfortable:

5) I felt comfortable being touched on the ______________ (Circle a number below)

Strongly disagree strongly agree
1 2 3 4 5 N/A

Please indicate why you felt comfortable or uncomfortable:

6) I felt comfortable being touched on the ______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

7) I felt comfortable being touched on the _____________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

8) I felt comfortable being touched on the _____________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

9) I felt comfortable being touched on the _____________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

10) I felt comfortable being touched on the _____________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

11) I felt comfortable being touched on the ______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

12) I felt comfortable being touched on the ______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

13) I felt comfortable being touched on the ______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

14) I felt comfortable being touched on the ______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

15) I felt comfortable being touched on the ______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

16) I felt comfortable being touched on the ______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

17) I felt comfortable being touched on the ______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

18) I felt comfortable being touched on the ______________ (Circle a number below)

Strongly disagree strongly agree

1 2 3 4 5 N/A

Please indicate why you felt comfortable or uncomfortable:

19) I felt comfortable being touched on the ______________ (Circle a number below)

Strongly disagree strongly agree

1 2 3 4 5 N/A

Please indicate why you felt comfortable or uncomfortable:

20) I felt comfortable being touched on the ______________ (Circle a number below)

Strongly disagree strongly agree

1 2 3 4 5 N/A

Please indicate why you felt comfortable or uncomfortable:

21) I felt comfortable being touched on the ______________ (Circle a number below)

Strongly disagree strongly agree

1 2 3 4 5 N/A

Please indicate why you felt comfortable or uncomfortable:

22) I felt comfortable being touched on the ______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

23) I felt comfortable being touched on the ______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

24) I felt comfortable being touched on the ______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

Is there anything else you would like to share with us?

Hands On: A Usability Study For Clothing Computers

Questionnaire for Person Performing the Touches

Subject:

Date: _________________ (DD/MM/YYYY)

Gender: M F

Gender of interaction partner (person you are touching): M F

Sexual Orientation: _________________ I choose to not disclose this info

Would you consider your partner a stranger? Y N
If no, please indicate your relationship to this person:

Photo Finding Task

For the following questions, you will be asked to provide a number to rate how much you agree or disagree on a statement. The rating scale is as follows:

1 = Strongly disagree
2 = Disagree
3 = Neutral
4 = Agree
5 = Strongly agree

If you or your partner chose to opt out of any task, circle N/A for the corresponding question.

For reference to the body parts, please refer to the body map provided to you.

---

1) I found it difficult to touch my partner on his/her ______________ (Circle a number below)

Strongly disagree strongly agree

1 2 3 4 5 N/A

2) I felt comfortable touching my partner on his/her _______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

----

3) I found it difficult to touch my partner on his/her _______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

4) I felt comfortable touching my partner on his/her _______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

----

5) I found it difficult to touch my partner on his/her _______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

6) I felt comfortable touching my partner on his/her _______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

----

7) I found it difficult to touch my partner on his/her ______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

8) I felt comfortable touching my partner on his/her ______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

----

9) I found it difficult to touch my partner on his/her ______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

10) I felt comfortable touching my partner on his/her ______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

----

11) I found it difficult to touch my partner on his/her ______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

12) I felt comfortable touching my partner on his/her ______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

----

13) I found it difficult to touch my partner on his/her _______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

14) I felt comfortable touching my partner on his/her _______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

----

15) I found it difficult to touch my partner on his/her _______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

16) I felt comfortable touching my partner on his/her _______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

----

17) I found it difficult to touch my partner on his/her _______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

18) I felt comfortable touching my partner on his/her ______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

---

19) I found it difficult to touch my partner on his/her ______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

20) I felt comfortable touching my partner on his/her ______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

---

21) I found it difficult to touch my partner on his/her ______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

22) I felt comfortable touching my partner on his/her ______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

----

23) I found it difficult to touch my partner on his/her _______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

24) I felt comfortable touching my partner on his/her _______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

25) I found it difficult to touch my partner on his/her _______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

26) I felt comfortable touching my partner on his/her _______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

---

27) I found it difficult to touch my partner on his/her _______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

28) I felt comfortable touching my partner on his/her _______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

---

29) I found it difficult to touch my partner on his/her _______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

30) I felt comfortable touching my partner on his/her _______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

---

31) I found it difficult to touch my partner on his/her _______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

32) I felt comfortable touching my partner on his/her _______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

----

33) I found it difficult to touch my partner on his/her _______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

34) I felt comfortable touching my partner on his/her _______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

----

35) I found it difficult to touch my partner on his/her _______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

36) I felt comfortable touching my partner on his/her _______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

----

37) I found it difficult to touch my partner on his/her _______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

38) I felt comfortable touching my partner on his/her _______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

----

39) I found it difficult to touch my partner on his/her _______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

40) I felt comfortable touching my partner on his/her _______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

---

41) I found it difficult to touch my partner on his/her _______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

42) I felt comfortable touching my partner on his/her _______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

---

43) I found it difficult to touch my partner on his/her _______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

44) I felt comfortable touching my partner on his/her _______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

---

45) I found it difficult to touch my partner on his/her _______________ (Circle a number below)

Strongly disagree				strongly agree	
1	2	3	4	5	N/A

46) I felt comfortable touching my partner on his/her ______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

----

47) I found it difficult to touch my partner on his/her ______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

48) I felt comfortable touching my partner on his/her ______________ (Circle a number below)

Strongly disagree strongly agree

1	2	3	4	5	N/A

Please indicate why you felt comfortable or uncomfortable:

Is there anything else you would like to share with us?