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ASSESSING THE USABILITY OF A WEARABLE COMPUTER INTERFACE WITH SPLIT BUTTON CONFIGURATION

by

Lisa A. Jamba

A thesis submitted to the
School of Computing
in partial fulfillment of the requirements
for the degree of

Master of Science in Computer and Information Sciences

UNIVERSITY OF NORTH FLORIDA
SCHOOL OF COMPUTING

March 2011

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The thesis "Assessing the Usability of a Wearable Computer Interface with Split Button Configuration" submitted by Lisa A. Jamba in partial fulfillment of the requirements for the degree of Master of Science in Computer and Information Sciences has been

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ABSTRACT

A wearable computer interface with split button configuration was constructed using Arduino Lilypad components on the front of a vest with the goal of assessing its usability in an activity involving at least one hand. A sample of twelve men and eight women ages 18 to 62 participated in a usability study of the vest. The activity chosen for this study was a typing test during which users would control a media player remotely with the vest. The usability measures included ease of use, performance of the interface as determined by accuracy rates and time to task completion for both button pressing and the typing test, and comfort. Results indicate the participants found the vest easy to learn and use with no significant effect on the accuracy of the typing activity, but they often needed visual cues to locate the controls. Based on these findings, we offer suggestions for improving the design of the interface and future work we want to pursue after the modifications.

Chapter 1

INTRODUCTION

Wearable computer interfaces (WCIs) are input/output devices worn in the user's personal space to control a computer-based system. They are meant to travel with the user, that is, they are “always accessible by the user” and allow the user to perform other tasks concurrently while being worn [Holleis08]. Examples of WCIs that have gained in popularity in recent years are Bluetooth-enabled headsets and wristwatches that communicate with other Bluetooth-enabled technologies, such as personal computers, mobile phones, and automobiles. The Bluetooth product directory lists in the headset category alone over 1160 products [Bluetooth11]!

Some people, though, will not use interfaces like headsets or watches for a variety of reasons including the rigor of the activities they engage in, as well as matters of comfort or aesthetics. Thus, there is room in the WCI marketplace for products made of materials other than molded plastics and worn on parts of the body other than the ear and wrist.

Advances in processing chips, power supplies, materials, and textiles have made it possible to integrate a computer interface directly onto or into a user's clothing. This blend of computing and textiles is referred to as electronic textiles or e-textiles. A history of how electronic textiles have evolved and an overview of this research area are well documented in [Marculescu03]. While e-textiles are not in the mainstream yet, there are some vendors offering 'smart textile' clothing such as Koyono's BlackCoat MFI series, which uses Eleksen's smart fabric touchpads to control media players [Koyono11, Eleksen11]. Touchpads like Eleksen's and those constructed in other wearable interface studies have buttons arranged linearly or in a cross formation similar to those found on media players or remotes for media players [Holleis08]. These configurations group buttons closely together and are usually solely on one side of the body in areas like the sleeve, upper pant leg, or inside the lapel of a shirt or jacket. We were interested in designing and evaluating a wearable interface with a different configuration that splits the buttons to both sides of the body and anchors the buttons close to seams to aid users in locating them without looking.

1.1 Contributions

Our goal was to develop a wearable interface with a split button configuration that is easy to learn and use, especially during activities where at least one hand is in use. The main contribution of this thesis is the determination of the usability of our split button interface designed to be worn on the front of the upper body. We also provide an explanation of our design decisions, highlighting selected guidelines from the wearable computing literature we followed. Additionally, we share recommendations for improving the design, based on the results of our usability testing.

1.2 Organization

In the next chapter of this thesis, we describe the objectives and research questions under consideration. In Chapter 3 we provide an overview of wearable computing literature, focusing on studies that have tested the usability of wearable interfaces. In Chapter 4, we summarize design guidelines from various sources and review our design decisions for the wearable interface. We also list the hardware and software components needed to construct the interface.

In Chapter 5, we discuss the usability testing process. We describe the targeted participants and the testing environment. We outline the procedures followed in the testing sessions and the types of data collected during those sessions. We summarize the results of the data analysis in Chapter 6. Finally, in Chapter 7 we discuss our findings, describe the strengths and limitations of our study, and suggest future research paths.

Chapter 2

OBJECTIVES AND RESEARCH QUESTIONS

The main objectives of this exploratory study were to examine the effectiveness of the placement of the controls for a wearable interface and to recommend possible improvements to the interface's design. Our specific research questions included:

1. How easily can users find the controls?
2. What is the performance of the interface determined by accuracy rates and time to complete tasks?
3. What patterns emerge, if any, in the hand choice to reach for the controls?
4. Are users comfortable wearing the prototype?
5. What obstacles do users identify with using the controls?

Chapter 3

RELATED WORK

In this chapter, we present work on evaluating computer interfaces that have similar locations or purposes as ours. In section 3.1, we summarize the results of usability studies of WCIs that involve placements of controls on the frontal regions of the torso and upper body. In section 3.2, we review recent usability studies that include controls used for media players, the primary use of our prototype.

3.1 Evaluating WCIs on Front Regions of the Body

While there are numerous studies describing wearable prototypes applied to a variety of application domains such as safety, health, or social needs, we focus this section on those that evaluated some aspect of the user experience of a WCI worn on the frontal regions of the body. We summarize the relevant findings of such studies and discuss the implications to our work.

The decision to locate an interface on regions of the torso or upper body often are related to the concurrent activities the user's are expected to be doing while wearing the interface. In one study, the interface was a belt with accelerometers, which controlled the objects of a game through motions of the hips and torso [Berkovsky10]. One goal of the belt was to encourage game players to be more active in the gaming session, without decreasing their level of enjoyment in playing the game. Their results showed no significant difference in enjoyment of the game between the groups who wore the interface and those who did not wear it.

Another group of researchers used a grid of vibration motors worn across the abdomen to help users track movements of objects while blindfolded [Bird09]. In their paper, they described the many stages of prototyping a "Tactile Vision Sensory Substitution (TVSS) system." This system has a camera and gloves that send tracking data to a microprocessor, which, in turn, determines which vibration motors should be activated on the grid worn by the user. These vibrations cue users on where the ball is relative to them, so they can hit it. Their later prototypes were tested on over 100 children and parents, yielding results that demonstrate the system was quick to learn and well tolerated.

As part of a larger project on science education, researchers created a vest known as the "SensVest" to collect physical activity data while users exercised [Knight05]. Their work documented the evolution of their garment from a shirt to a vest and the types and sizes of sensors needed to collect measurements while not degrading the comfort of the garment. They studied users wearing their last prototype and found the vest did not interfere with the user's activities, the vest was comfortable to wear, and the sensors worked reliably.

In studies by [Holleis08], they created a variety of prototypes with integrated controls, such as an accessory bag, bike helmet, glove, and apron. In one set of user studies, they showed participants the bag, helmet, and glove and asked their perceptions of using these devices and placements of wearable interfaces in general. In another set of user studies, they asked participants to wear an apron that had controls sewn onto it. Participants used the apron while sitting and controlling a display on a seat in front of them and while simulating cooking in a kitchen and controlling common household devices like the stereo and TV. With respect to the placement of the controls on the body across these studies, they found users would more likely consider using controls in public, if they are integrated in garments like trousers (on the upper thigh) or wrist bands and less likely to use them in shirts or scarves (on the upper body).

The first three studies mentioned in this section involve WCIs that are more passive in nature, that is, input is collected through sensors automatically. These studies illustrate that in terms of passive interfaces worn above the waist the users did not experience degradation in their activity performance or comfort. Participant feedback in the last study suggested the upper body might not be an optimal location for controls. However, the performance of the controls they placed on other regions like the upper thigh suffered because of fabric bending and shifting. We wanted our design to be usable in both stationary and mobile situations and some of the studies indicated the upper body still might be a good candidate location. Consequently, we chose to place the controls in the upper chest and neck region where there are no joints and garments are less likely to shift.

3.2 Evaluating Interfaces Used for Controlling Media

We summarize here findings from studies where interfaces with controls used for media devices were tested for performance. In the work by Holleis et al., the studies involving the apron interface had three types of button clusters – visible, ornamental buttons, and invisible. The visible buttons were embroidered onto the fabric as shapes typically found in media player controllers. The ornamental buttons looked like those found on traditional garments to enhance the look or make it more fashionable (e.g. small beads or snaps). The invisible buttons were touch input that blended into the fabric but could be sensed through touch by being slightly raised. With respect to these button types, the task performance of users was lower for the invisible buttons than the other types, and all three types had lower performance when users did not look at the controls [Holleis08].

Remote controls for media players have traditionally used standard press buttons to get input from users to control the player, but touch input seems to be gaining in popularity with some products in the market. A group of researchers recently compared performance and user perceptions of standard remotes versus touch remotes to control interactive TV [Pirker10]. They found participants had higher error rates with the touch input remote, but from an aesthetic point of view they preferred the look of it. The participant's perceptions of the accuracy of the two types of input buttons indicates some people are unlikely to buy a touch input remote until it is easy to use and provides timely feedback.

In these studies, the participants' task performance and perceptions differed based on the visibility of the button and the type of button (press versus touch). Considering one of the goals was to design a wearable interface that is easy to use and reliable in a variety of activities, we chose to use press buttons for input at the risk of our garment being perceived as less attractive, a decision that appears to be supported by other studies.

Chapter 4

DESIGNING THE WEARABLE INTERFACE

In this chapter, we provide a list of design guidelines we used to inform our interface design, as well as the design decisions we made (section 4.1). We also provide a summary of the hardware and software materials needed to construct the prototype we used in the usability testing (section 4.2).

4.1 Design Guidelines & Decisions

We used portions of two sets of guidelines to help inform our wearable computer interface design. These guidelines are briefly described in this section along with how we chose to address them.

4.1.1 Design Guidelines for Wearability

The "Design Guidelines for Wearability" list thirteen guidelines of varying complexity [Gemperle98]. We felt seven of the thirteen guidelines were applicable to the vest we were constructing. Table 1 shows the guidelines and our decisions on constructing the vest that map to them.

Guideline for Wearability	**Description**	**Our Vest**
Placement	Placing object in areas of the body similar in size across users and larger in surface area	Buttons are located on the front upper body in the collar area and upper torso, power supply is located on back just below neck
Human Movement	Placing object so it will not interfere with the user's movements	Buttons are not located on a joint that would prohibit movement of arms or torso
Proxemics	Objects should remain inside a user's personal space	Buttons are small in size and do not protrude beyond an inch from the vest's surface
Sizing	Objects should be able to accommodate user's of different body types	Buttons are located along the seams of the zipper of the vest, so the variability would be the size of the vest and the length of the conductive threads
Sensory Interaction	Keep passive and active interaction with the objects simple and intuitive	Buttons are shaped into rectangular tabs that can be gripped; require single actions to operate
Aesthetics	The look and feel of the objects should be appealing to the user	Buttons are sewn onto a fleece vest with a neutral color
Long Term Use	Keep in mind how repeated use might affect the user's body	Buttons on the front of the body require small movements of the arms

Table 1: Design Guidelines for Wearability

4.1.2 Developing Wearable Interfaces

The second set of guidelines we used resulted from research on several wearable accessories including phone bags, helmets, gloves, and aprons [Holleis08]. Table 2 shows these guidelines along with our decisions on constructing the vest that map to them.

Guidelines when Developing Wearable Interfaces	**Description**	**Our Vest**
There are no clear expectations on layout and meaning	User's are open to new arrangements of objects	Reserve buttons on the right side for actions such as forward/up/play and the left side for backward/down
Location and identification must be quick and easy	Objects should be visible and tangible and easy to find while doing other tasks	Buttons are shaped into rectangular tabs that protrude slightly from the vest; located along the seam of the zipper; separated by at least three finger widths
Ensure one-handed interaction	Objects should only require one hand to use	Buttons can be pressed with one hand from either side of the body
Provide immediate feedback	Minimal delay between the user's action and the result of that action	Use a processor and buttons that respond quickly

Table 2: Guidelines when Developing Wearables

4.2 Constructing the Wearable Interface

In this section, we present the hardware (Section 4.2.1) and software (Section 4.2.2) components used to construct the wearable interface on the vest.

4.2.1 Hardware

The wearable interface's hardware components used in this study originated from projects and research started at the Craft Technology Group at the University of Colorado at Boulder. Researchers at this group developed prototypes of microcontrollers, sensors, and power supplies that could be sewn onto other materials and connected with conductive thread. They packaged these materials as a construction kit and tested the usability of the kit with varying audiences [Buechley06]. Their positive results on the usability of such as kit for constructing wearable interfaces and the flexibility it offers when doing rapid prototyping are reasons we selected the most recent generation of the kit, known as the LilyPad Arduino, for our project [Buechley08, Buechley10, SparkFun11]. We purchased six LilyPad Button Boards and the LilyPad Deluxe kit (now deprecated), which included the following: a

LilyPad 328 Mainboard; a LilyPad Power Supply; an FTDI Basic Breakout; a Mini USB cable, and 234/34 conductive thread. These components were used to construct and program our vest.

We sewed the Mainboard and power supply onto felt patches that were sewn onto the outer rear portion of the vest just below the neckline (Figure 1). We connected the buttons to the MainBoard using conductive thread, and then covered each button with felt patches to protect the contacts (Figure 2). A full view of the front and back of the vest are show in Figures 3 and 4.

Figure 1: Mainboard and
Power Supply on Back of Vest

Figure 2: Button Board on
Front of Vest

Figure 3: Front View of Prototype

Figure 4: Rear View of Prototype

4.2.2 Software

To program the LilyPad 328 MainBoard, we used Arduino software version 17 [Arduino11]. We followed a tutorial to set up the programming environment and ensure communication between the MainBoard and computer on the proper serial port [Beuchley09]. The Arduino program for the controls on the vest is found in Appendix A, which uses a button library for Arduino to determine when the user presses a button on the vest [Brevig09].

Given pressing the buttons results in the MainBoard printing ASCII text to the serial port, we used AACKeys to translate the text received through the serial port into keystrokes [AACKeys07]. These keystrokes were recognized by a utility program, AutoHotKey version 1.0.48.05, which required scripts to send commands to the Windows Media Player and to display dialog boxes to the participants during the usability testing [Mallett09, Microsoft10]. The scripts written for the testing sessions are in Appendices B and C.

Chapter 5

RESEARCH METHODOLOGY

In order to evaluate the research questions related to the usability of the button configuration on the vest, an exploratory user study was performed. In this chapter, we discuss the research methodology of this study. In Section 5.1, we describe our recruitment strategies to find study participants. In Section 5.2, we explain the testing environment, including the layout of the room in which the sessions took place. In Section 5.3, we outline the procedures we followed during a testing session. We list the types of data we collected in Section 5.4.

Prior to any recruiting or testing, we submitted the study for approval by our Institutional Review Board (IRB). A copy of the approval is found in Appendix F.

5.1 Recruitment Strategies

To find participants at a moderate-sized university, we advertised the study on flyers distributed in courses that typically enroll a diverse group of students, including lower-level computing courses and general education courses. We also posted flyers in common areas of the university, such as general purpose computing labs, food courts, and advising offices. The flyer outlined the general purpose of the study, the criteria to participate, and gave a link to a website to reserve an appointment time.

Interested participants used the online scheduling system, SuperSaas, to register and select an available appointment time [SuperSaas10]. Participants selected their own SuperSaas account identifiers and completed a registration form that only collected screening information to ensure they met the qualifications for the study, which included being age 18 or older and being able to type on a keyboard and press buttons. Each person chose an available one-hour block of time and could return at anytime to the system to modify or cancel the appointment. After scheduling an appointment, the participant received an e-mail confirming the appointment time and giving the location of the usability laboratory.

5.2 Testing Environment

To prepare for the testing session, we configured an office to include an observation area and a testing station. This environment is described below.

5.2.1 Testing Station

The testing station consisted of a desk, a seat with adjustable height, and a laptop computer with a combination webcam/microphone and mouse attached. The laptop contained the following: (1) AACKeys, which translated the text sent through the serial port into keystrokes [AACKeys07]; (2) two scripts written to control the media player using the keystrokes and to prompt the user at various times to push a button on the vest; (3) TypingMaster Typing Test version 6.30, which tracked accuracy of timed typing tasks [TypingMaster11]; (4) BB Flashback Standard version 2.7.3, which recorded video, sound, screenshots, and keystrokes [Blueberry10]); and (5) Windows Media Player 11 [Microsoft11].

5.2.2 Observation Area

As seen in Figure 5, the observation area was a chair and small table to the right of the testing station and slightly behind the participant's line of sight. This particular angle allowed us to make note of any special behaviors by the participants or issues with the laptop or vest during the session.

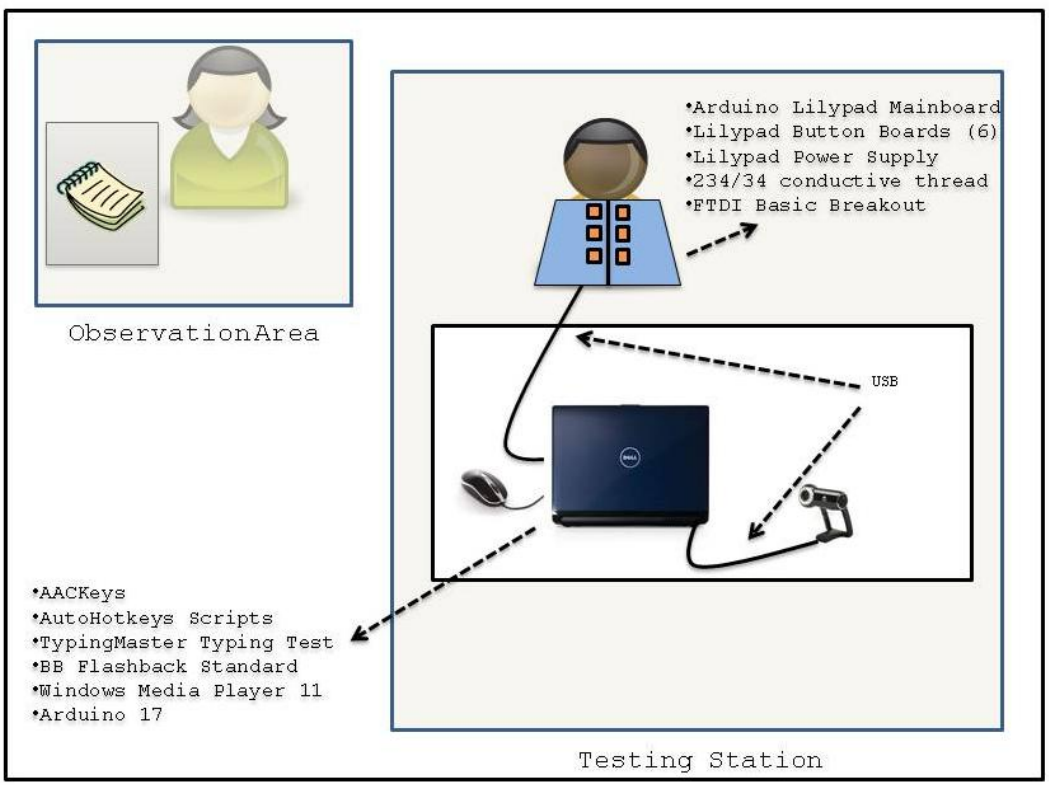

Figure 5: Testing Environment

5.3 Testing Sessions

At the start of a testing session, we reviewed the Informed Consent Form with the participant and addressed any questions or concerns. After the Consent was signed, we thanked the participant for agreeing to be in the study and summarized the activities for the session. We encouraged participants to talk out loud during the activities. We reiterated the investigator in the room would be watching and taking notes as the tasks were completed, but would try to be as unnoticed as possible. We asked the participant to put on the vest and sit at the testing station. Once the participant was seated with the vest on, we started recording the session on the laptop.

We gave a questionnaire to the participant to provide background information about their age, gender, and technology and media use (see Appendix D). Then, in the training segment, we executed the training script, explained each button, and allowed the participant to practice using the vest’s controls for the media player.

After the training segment, we started the typing program, which gave a typing test for five minutes and recorded baseline assessments of words per minute typing speed and error rates. Next, we started the testing session script and restarted the typing program, so they were running concurrently for a five-minute interval. The script, which temporarily interrupted the typing activity and forced the use of at least one hand, prompted the participant at irregular intervals to use the vest to control the media player.

At the conclusion of the second typing task, we asked the participant to complete an exit survey (see Appendix E). In some sessions, we asked follow up questions based on events observed in the sessions that we felt needed further exploration. Once the participant completed the exit survey, we stopped the recording and saved the session on a secure drive.

5.4 Data Collection

We gathered measures by observing participants directly and reviewing the videos of the sessions. For each participant, we collected (1) the number of buttons pressed using only tactile clues (i.e. the person did not look at the button), (2) the difference in accuracy rates in the typing activities, (3) the difference in words per minute in the typing activities, (4) the number of buttons wrongly pressed (i.e. different from what the window prompted) (5) the length of time between prompting the user to pressing each control, (6) the number of buttons pressed by the hand from the opposite side of the body, which we refer to as 'crossover', (7) responses on the System Usability Scale (SUS) and modified portions from the Comfort Rating Scale (CRS) used to measure comfort factors for wearable computers, and (8) free responses about the suggested improvements to the controls [Brooke96, Knight02].

Chapter 6

RESULTS

In this section, we present a summary of the demographics of the participants (section 6.1) and the analyses of the data collected from the participants in terms of performance (section 6.2) and comfort and acceptability (section 6.3).

6.1 Participants

Twenty adults, ages 18 to 62, participated in usability testing sessions. Table 3 shows the participants' demographics. The average age was 30.20 years (SD = 12.090) and almost all (95%) of the participants were right-handed. Sixty percent were male.

Category	n	%
Gender		
Female	8	40.00
Male	12	60.00
Age Ranges		
0-25	9	45.00
26-35	7	35.00
36-45	1	5.00
46-55	1	5.00
56-65	2	10.00
> 65	0	0.00
Handedness		
Ambidextrous	0	0.00
Right-handed	19	95.00
Left-handed	1	5.00

Table 3: Participant Demographics

Table 4 shows the distribution of the participants' usage of wearable devices and media players. For devices worn on or in the ears, a large portion of participants rarely or never used Bluetooth headsets (75%) and half rarely or never use headphones with built in controls (50%). Fifty-five percent wear a wristwatch at least occasionally. In terms of digital media players used at least occasionally, 85% reported using a player on a computer and 90% reported using a portable. Only 20% percent of respondents reported using a remote to control such players at least occasionally. There were not significant differences in usage between men and women with respect to each category.

Category	Female	Male	n	%
Bluetooth Headset				
Never	1	5	6	30.00
Rarely	4	5	9	45.00
Occasionally	0	0	0	0.00
A moderate amount	1	2	3	15.00
A great deal	2	0	2	10.00
Digital Music Player – on Computer				
Never	0	0	0	0.00
Rarely	1	2	3	15.00
Occasionally	2	2	4	20.00
A moderate amount	2	2	4	20.00
A great deal	3	6	9	45.00
Digital Music Player – Portable				
Never	0	2	2	10.00
Rarely	0	0	0	0.00
Occasionally	3	1	4	20.00
A moderate amount	3	2	5	25.00
A great deal	2	7	9	45.00
Headphones with Controls				
Never	2	2	4	20.00
Rarely	3	3	6	30.00
Occasionally	3	2	5	25.00
A moderate amount	0	5	5	25.00
A great deal	0	0	0	0.00
Remote for Media Player				
Never	3	4	7	35.00
Rarely	3	6	9	45.00
Occasionally	1	0	1	5.00
A moderate amount	0	2	2	10.00
A great deal	1	0	1	5.00
Watch				
Never	1	4	5	25.00
Rarely	1	3	4	20.00
Occasionally	1	2	3	15.00
A moderate amount	0	1	1	5.00
A great deal	5	2	7	35.00

Table 4: Device and Media Player Usage

6.2 Performance Measures

We had several performance measures in this study. This subsection presents the analysis of the measures related to finding buttons, selecting hands, timing and accuracy of pressing buttons on the vest, and to timing and accuracy of the typing tasks.

6.2.1 Finding Buttons

To measure how easily users can find the controls, we estimated the proportion of tasks where participants used visual cues to locate the controls. Of the total attempts to press a button when prompted (n=294) among all participants, 213 looked at the vest to find the button. The best point estimate for this measure is .723 with an adjusted Wald 95% CI [0.67, 0.772]. The percentage of visual cues did significantly differ by button, $\chi^2(4, N = 294) = 20.889$, $p = .000$. Table 5 shows the crosstabulation of visual cues by button location.

Button	**Location**	**Visual Cue**	**Total**	**%**
Volume Up	Middle right	50	60	83.33
Volume Down	Middle left	32	39	82.05
Next	Bottom right	30	38	78.95
Previous	Bottom left	47	60	78.33
Play	Top right	54	97	55.67

Table 5: Crosstabulation of Visual Cues by Button

6.2.2 Hand Selection

In addition to estimating the proportion that used visual cues, we also wanted to study patterns that emerged from the hand chosen to reach for the controls. Of the total attempts to press a button when prompted (n=294) among all participants, 79 used the hand from the opposite side of the body to press it. We refer to this as "crossover." The best point estimate for this measure is .2703 with an adjusted Wald 95% CI [0.2212, 0.3222]. The percentage of crossover did significantly differ by button, $\chi^2(4, N = 294) = 32.870$, $p = .000$. Table 6 shows the distribution of crossover by button location.

Button	**Location**	**#Crossover**	**n**	**%**
Previous	Bottom left	30	60	50.00
Volume Down	Middle left	17	39	43.59
Play	Top right	17	97	17.53
Next	Bottom right	6	38	15.79
Volume Up	Middle right	9	60	15.00

Table 6: Crosstabulation of Crossover by Button

We examined the crossover behavior by participant and one-fourth (25%) had no cases of crossover to press buttons.

6.2.3 Timing and Accuracy of the Button Pressing Task

With this being the first study on this particular configuration and placement of the buttons on the vest, we collected descriptive statistics on the time participants needed from being prompted on the screen to pressing a button on the vest. The mean time to press a button was 3.388 seconds (*SD* = 1.465), but this task's time distribution did not appear normal, so we applied a log transformation, resulting in the 95% CI [3.02, 3.29].

We estimated the proportion of tasks where participants selected the wrong button, i.e. a task error. Of the total attempts to press a button when prompted (n=294) among all participants, 58 had the wrong button pressed. The best point estimate for this measure is .1791 with an adjusted Wald 95% CI [0.1373, 0.2248]. The error rate did not significantly differ by button location.

6.2.4 Timing and Accuracy of the Typing Tasks

When using the vest while doing a concurrent task like typing, we wanted the participant's performance in the task not to degrade significantly. We measured each participant's typing speed as words per minute (WPM) and accuracy rate as percentage of words typed correctly from a passage, in both a baseline session (no vest use) and testing session (vest use).

The mean WPM for the baseline session was 41.40 (SD = 14.144) and for the testing session was 31.95 (SD = 13.543). A paired t-test showed the difference in typing speeds was statistically significant, $t(19) = 6.652$, p = .000. The accuracy rates from the baseline session ranged from 77% to 99% and from the testing session ranged from 74% to 99%. A paired t-test did not reveal significant differences in accuracy rates $t(19) = 0.410$, p=0.686.

6.3 Comfort and Acceptability Measures

We asked participants to rate statements on comfort and acceptability of the vest on a Likert rating scale from 1 to 5 for *Strongly Disagree (1-SD)* to *Strongly Agree (5-SA)*, respectively. Table 7 summarizes the responses.

	1-SD	**2-D**	**3-N**	**4-A**	**5-SA**	Mean	*SD*
I imagine most people would learn to use this vest very quickly.	0.0% (0)	0.0% (0)	0.0% (0)	60.0% (12)	40.0% (8)	4.40	0.503
The vest is comfortable to wear.	0.0% (0)	0.0% (0)	5.0% (1)	60.0% (12)	35.0% (7)	4.30	0.571
I thought the vest was easy to use.	0.0% (0)	0.0% (0)	10.0% (2)	75.0% (15)	15.0% (3)	4.05	0.510
I found the various functions in the vest were well integrated.	0.0% (0)	5.0% (1)	10.0% (2)	75.0% (15)	10.0% (2)	3.90	0.641
I would buy clothes with controls built in.	0.0% (0)	15.0% (3)	15.0% (3)	40.0% (8)	30.0% (6)	3.85	1.040
I felt very confident using the vest.	0.0% (0)	5.0% (1)	55.0% (11)	20.0% (4)	20.0% (4)	3.55	0.887
I think I would like to use this vest frequently.	0.0% (0)	21.1% (4)	36.8% (7)	42.1% (8)	0.0% (0)	3.21	0.787
I worry about how I look when I wear the vest.	35.0% (7)	10.0% (2)	10.0% (2)	45.0% (9)	0.0% (0)	2.65	1.387
I found the vest very awkward to use.	15.0% (3)	50.0% (10)	20.0% (4)	15.0% (3)	0.0% (0)	2.35	0.933
I found the vest unnecessarily complex.	30.0% (6)	60.0% (12)	10.0% (2)	0.0% (0)	0.0% (0)	1.80	0.616
I feel tense or on edge, because I am wearing the vest.	50.0% (10)	40.0% (8)	5.0% (1)	5.0% (1)	0.0% (0)	1.65	0.813

	1-SD	**2-D**	**3-N**	**4-A**	**5-SA**	Mean	*SD*
I thought there was too much inconsistency in this vest.	55.0% (11)	40.0% (8)	5.0% (1)	0.0% (0)	0.0% (0)	1.50	0.607
I needed to learn a lot of things, before I could get going with this vest.	60.0% (12)	30.0% (6)	10.0% (2)	0.0% (0)	0.0% (0)	1.50	0.688
I think I would need the support of a technical person to be able to use this vest.	80.0% (16)	20.0% (4)	0.0% (0)	0.0% (0)	0.0% (0)	1.20	0.410

Table7: Summary of Ratings for Comfort and Acceptability

We asked participants at the end of the exit questionnaire to list two things they would do to improve the vest. The free responses were categorized into (1) button position, (2) button properties, (3) control actions, (4) hardware, and (5) garment properties.

With respect to button position, 25% (n = 5) of the participants suggested moving them lower on the vest. Two participants wanted the buttons closer together while one suggested they be farther apart. One person recommended the buttons be placed on the arm or sleeve. One person commented it would be better to have buttons closer to the work surface, but did not suggest how to do this on the vest.

There were numerous suggestions for changing the button properties. Three participants suggested labeling the buttons, two wanted them larger, and one person wanted raised markings on the button material. Others offered ideas that would make the buttons less prominent including making it flush with the garment or invisible.

While most did not comment on the actions of the controls, three people wanted more controls, that is, they wanted more buttons that did more with the player. One participant suggested the controls should be motion activated and another person would have preferred some sort of visual feedback when the volume buttons were used. Two participants commented on adding additional hardware to the vest. One participant wanted the speakers and music player built into the vest itself. Another participant suggested the vest be Bluetooth enabled.

Participants also offered feedback on the garment's properties. Twenty-five percent (n = 5) said the vest should be more stylized, which included a different color scheme or design elements. Three participants would have preferred the vest be constructed differently or use fabric other than fleece.

Chapter 7

DISCUSSION & FUTURE WORK

In this chapter, we discuss our findings from our usability study in section 7.1. We suggest improvements to our design in section 7.2 and suggest the directions our future work may go in section 7.3.

7.1 Findings

We collected a variety of data points from our twenty participants to use for design evaluation purposes. While we had hoped to have an equal number of men and women participate, we considered our sample to be representative with 12 men and 8 women. Our data suggests that while the vest was relatively easy to learn and use, the location of the buttons should be reconsidered in order to have users find them without looking. Users had to look most often for the buttons placed in the center row (mid-chest region) to raise the volume up and down.

The action we referred to as "crossover" happened more often to press the bottom left button used to go to the previous song. Given almost all of our participants were right-handed, the results showed most participants preferred to use their dominant hand to use the interface. The average time it took participants to press a button after being prompted was a little over three seconds, so with repeated use and thus small delays needed to press the buttons, we expected to see an effect on the performance time for the concurrent typing task. This indeed was the case, with significant decreases in typing speed in trials using the vest.

The confidence interval of the error rate for pressing the wrong button ranged from approximately 14% to 22%. We hope to see this error rate decrease with improvements made to the design.

The accuracy rates of the typing tasks did not significantly degrade from using the interface. This was an indication the vest was not interfering with the concurrent typing activity.

We found in the participants' feedback that overall they found the vest easy to use, felt little technical support would be needed to use it, and others could learn to use it quickly. They felt the vest was comfortable to wear, but almost half had concerns about how they looked wearing it. Participants had mixed opinions about how often they would use it and if they would purchase clothes with built in controls like the vest.

The participants offered numerous suggestions for improving the interface, most of which related to the button placement and look and feel of the interface and garment. A suggestion that was more notable was to lower the buttons on the vest, particularly those found at the collar. Most of the participants looked down to locate buttons and found those on the collar too high to see, thus had to just use tactile cues to find them. Another notable suggestion was to change the color scheme or design elements of the vest to make it look more appealing to wear.

7.2 Improving the Design

Based on these findings and suggested improvements, we plan to change the interface slightly. First, we need to address the placement of the buttons by considering what lower regions on the front of the vest would be acceptable, but high enough not to be affected by folds in the garment when sitting or bending. One participant suggested fastening the buttons to some sort of adjustable track so users can position the buttons to their taste, which we find to be very promising. The second modification would be in the design of the buttons themselves. We observed the button size was adequate to ensure users could grasp them easily, but would like to reduce the size of the button and make their appearance more fashionable. We are not convinced moving to a touch input button would be advantageous, especially since this suggestion was not mentioned by any of the participants.

7.3 Future Work

After modifying the interface, we look forward to conducting more usability studies that involve comparisons of our interface to other wearable interfaces. We are particularly interested in differences that might arise from the split button configuration versus the clustered buttons mentioned in Chapter 1. We would also like to test the vest in use during other activities such as walking, cycling, or driving. Additionally, we would like to explore if the usability ratings and performance are related to variables such gender and age, and examine the learning curves associated with using the vest controls.

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APPENDIX A

LilyPad Arduino Code

```
#include <Button.h> //import Button library

Button play = Button(2,PULLUP); //Create a button at pin 2
Button launch = Button(5,PULLUP); //Create a button at pin 5
Button voldown = Button(6,PULLUP); //Create a button at pin 7
Button previous = Button(9,PULLUP); //Create a button at pin 9
Button next = Button(10,PULLUP); //Create a button at pin 10
Button volup = Button(13,PULLUP); //Create a button at pin 13
int nextLow = 11; //Next button connected to pin 11
int prevLow = 8; //Previous button connected to pin 8
int downLow = 7; //Volume down button connected to pin 7
int upLow=12; //Volume up button connected to pin 12

void setup()  //initial setup runs once
{
  Serial.begin(9600); //establish serial port
  pinMode(nextLow, OUTPUT); //sets nextLow as output
  pinMode(prevLow, OUTPUT); //sets prevLow as output
  pinMode(downLow, OUTPUT); //sets downLow as output
  pinMode(upLow,OUTPUT); //sets upLow as output
}

void loop()
{
  if(launch.isPressed()) //print 1 when launch button pressed
  {
     Serial.print("1");
     delay(500);
  }
  if(play.isPressed())  //print 2 when play button pressed
  {
     Serial.print("2");
     delay(500);
  }
  if(voldown.isPressed())  //print 3 when voldown button pressed
  {
     Serial.print("3");
     delay(500);
  }
  if(volup.isPressed())  //print 4 when volup button pressed
  {
     Serial.print("4");
     delay(500);
```

```
  }
  if(previous.isPressed())  //print 5 when prev button pressed
  {
     Serial.print("5");
     delay(500);
  }
  if(next.isPressed())  //print 6 when next button pressed
  {
     Serial.print("6");
     delay(500);
  }
}
```

APPENDIX B

Testing Session AutoHotkey Script

```
; WMP Script
; AutoHotkey Version: 1.0.48.05
; Language:       English
; Platform:       WinXP/Vista
; Author:    Lisa Jamba, UNF
;
; Adapted from posts by Polyphenol on AutoHotKeys for itunes
; See http://www.autohotkey.com/forum/topic5727.html
;
; Script Function:
;   Control WMP with hotkeys and display windows that prompt user
;   to use the vest's controls during the testing session

;recommended for new scripts, improves performance
#NoEnv

;reload script when launched if already running
#SingleInstance force

;detects hidden windows
DetectHiddenWindows, on

;set match mode so window commands find correct window
SetTitleMatchMode 2

;prevent bug during typing test from WinXP caps issue
SetCapsLockState AlwaysOff

;display window prompting user to press play or pause button
PlayPause()
{
SplashTextOn, , , Press Play/Pause.
WinMove, Press Play/Pause., ,500,300
Return
}

;display window prompting user to press next button
Next()
{
SplashTextOn, , , Press Next.
WinMove, Press Next., ,500,300
Return
}
```

```
;display window prompting user to press previous button
Previous()
{
SplashTextOn, , , Press Previous.
WinMove, Press Previous., ,500,300
Return
}

;display window prompting user to press volume up button
Volup()
{
SplashTextOn, , , Turn Up the Volume.
WinMove, Turn Up the Volume., ,500,300
Return
}

;display window prompting user to press volume down button
Voldown()
{
SplashTextOn, , , Turn Down the Volume.
WinMove, Turn Down the Volume., ,500,300
Return
}

;pause between prompts, clear windows
Pause()
{
Sleep, 11000  ;allow 11 seconds for window to display
SplashTextOff ;clear window if user can't locate control
Sleep, 8000   ;wait 8 seconds before next command
}

;show sequence of windows prompting user
Sleep, 25000
PlayPause()
Pause()
Next()
Pause()
Volup()
Pause()
Voldown()
Pause()
Previous()
Pause()
Volup()
Pause()
PlayPause()
Pause()
PlayPause()
Pause()
Previous()
Pause()
```

```
Previous()
Pause()
Voldown()
Pause()
PlayPause()
Pause()
PlayPause()
Pause()
Next()
Pause()
Volup()
Pause()

;hotkey for keystroke 1 launches WMP if not open or
;minimize/maximize when open
1::
IfWinNotExist,Windows Media Player
{
Run %ProgramFiles%\Windows Media Player\wmplayer.exe  ;launch
program
WinActivate
WinMove,Windows Media Player,,0,0
return
}

IfWinExist,Windows Media Player; toggle minimize/restore
{
IfWinNotActive ; restores window
{
WinActivate
WinMove,Windows Media Player,,0,0
}Else
WinMinimize ; minimizes windows
return
}

;hotkey for keystroke 6 to advance WMP to next song, close window
;if pressed correct button
6::
SendInput, {MEDIA_NEXT down}{MEDIA_NEXT up}
IfWinExist, Press Next.
{
SplashTextOff
}
Return

;hotkey for keystroke 5 to go back to WMP previous song, close
;window if pressed correct button
5::
SendInput, {MEDIA_PREV down}{MEDIA_PREV up}
IfWinExist, Press Previous.
{
```

```
SplashTextOff
}
Return

;hotkey for keystroke 2 to play/pause WMP song, close window if
;pressed correct button
2::
SendInput, {Media_Play_Pause down}{Media_Play_Pause up}
IfWinExist, Press Play/Pause.
{
SplashTextOff
}
Return


;hotkey for keystroke 4 to turn up WMP volume, close window if
;pressed correct button
4::
SendInput,{Volume_Up down}{Volume_Up up}
IfWinExist, Turn Up the Volume.
{
SplashTextOff
}
Return

;hotkey for keystroke 3 to turn down WMP volume, close window if
;pressed correct button
3::
SendInput,{Volume_Down}{Volume_Down up}
IfWinExist, Turn Down the Volume.
{
SplashTextOff
}
Return


;endofscript
```

APPENDIX C

Training Session AutoHotkey Script

```
; WMP Training Script
; AutoHotkey Version: 1.0.48.05
; Language:       English
; Platform:       WinXP/Vista
; Author:    Lisa Jamba, UNF
;
; Adapted from posts by Polyphenol on AutoHotKeys for itunes
; See http://www.autohotkey.com/forum/topic5727.html
;
; Script Function:
;   Control WMP with hotkeys during training session

;recommended for new scripts, improves performance
#NoEnv

;reload script when launched if already running
#SingleInstance force

;detects hidden windows
DetectHiddenWindows, on

;set match mode so window commands find correct window
SetTitleMatchMode 2

;prevent bug during typing test from WinXP caps issue
SetCapsLockState AlwaysOff

;hotkey for keystroke 1 launches WMP if not open or
;minimize/maximize when open
1::
IfWinNotExist,Windows Media Player
{
Run %ProgramFiles%\Windows Media Player\wmplayer.exe  ;launch
program
WinActivate
WinMove,Windows Media Player,,0,0
return
}

IfWinExist,Windows Media Player; toggle minimize/restore
{
IfWinNotActive ; restores window
{
WinActivate
```

```
WinMove,Windows Media Player,,0,0
}Else
WinMinimize ; minimizes windows
return
}

;hotkey for keystroke 6 to advance WMP to next song
6::
IfWinExist, Windows Media Player
SendInput, {MEDIA_NEXT down}{MEDIA_NEXT up}
Return

;hotkey for keystroke 5 to go back to WMP previous song
5::
IfWinExist, Windows Media Player
SendInput, {MEDIA_PREV down}{MEDIA_PREV up}
Return

;hotkey for keystroke 2 to play/pause WMP song
2::
IfWinExist, Windows Media Player
SendInput, {Media_Play_Pause down}{Media_Play_Pause up}
return

;hotkey for keystroke 4 to turn up WMP volume
4::
IfWinExist, Windows Media Player
SendInput,{Volume_Up down}{Volume_Up up}
Return

;hotkey for keystroke 3 to turn down WMP volume
3::
IfWinExist, Windows Media Player
SendInput,{Volume_Down}{Volume_Down up}
return

;endofscript
```

APPENDIX D

Background Questionnaire

We would like to know some background information about you. Please answer the following questions before we move to trying the product for this study.

1. Select your gender:
   _ Female
   _ Male

2. What is your age (in years)?
   Age: ____________________

3. Are you right-handed, left-handed, or ambidextrous?
   _ Right-handed (use right hand mostly)
   _ Left-handed (use left hand mostly)
   _ Ambidextrous (use hands equally as often)

4. Mark how often you use the following:

	A great deal	A moderate amount	Occasi onally	Rarely	Never
A digital music player on a computer (e.g. iTunes, Windows Media Player)?					
A portable digital music player (e.g. iPod, MP3 player)?					
A remote to control a digital music player?					
A Bluetooth headset?					
A set of headphones with built-in controls?					
A watch worn on your wrist?					

APPENDIX E

Exit Survey

We would like to know your impressions about the activities today. Please answer the following questions before you go. Your feedback is important part of this study.

1. Please check the box that reflects your immediate response to each statement. Do not think too long about each statement. Make sure you respond to every statement. If you do not know how to respond, simply pick "3."

	1 Strongly disagree	**2 Disagree**	**3 Neither agree nor disagree**	**4 Agree**	**5 Strongly agree**
I think I would like to use this vest frequently.					
I found the vest unnecessarily complex.					
I thought the vest was easy to use.					
I think I would need the support of a technical person to be able to use this vest.					
I thought there was too much inconsistency in this vest.					
I found the various functions in the vest were well integrated.					

	1 Strongly disagree	2 Disagree	3 Neither agree nor disagree	4 Agree	5 Strongly agree
I imagine most people would learn to use this vest very quickly.					
I found the vest very awkward to use.					
I felt very confident using the vest.					
I needed to learn a lot of things, before I could get going with this vest.					
I feel tense or on edge, because I am wearing the vest.					
The vest is comfortable to wear.					
I worry about how I look when I wear the vest.					
I would buy clothes with controls built in.					

2. What two things would you do to improve the vest?

1. ____________________
2. ____________________

APPENDIX F

IRB Approval Notification

UNF
UNIVERSITY of
NORTH FLORIDA.

Office of Research and Sponsored Programs
1 UNF Drive
Jacksonville, FL 32224-2665
904-620-2455 FAX 904-620-2457
Equal Opportunity/Equal Access/Affirmative Action Institution

MEMORANDUM

DATE: April 21, 2010

TO: Ms. Lisa Jamba

VIA: Dr. Layne Wallace
School of Computing

FROM: Dr. Katherine Kasten, Chairperson
UNF Institutional Review Board

RE: Review by the UNF Institutional Review Board IRB#10-029:
"Assessing the Usability of a Wearable Computer Interface with Split Button Configuration"

This is to advise you that your project, "Assessing the Usability of a Wearable Computer Interface with Split Button Configuration," has undergone "expedited, category #6 & #7" review on behalf of the UNF Institutional Review Board and was approved.

This approval applies to your project in the form and content as submitted to the IRB for review. Any variations or modifications to the approved protocol and/or informed consent forms as they relate to dealing with human subjects must be cleared with the IRB prior to implementing such changes. Any unanticipated problems involving risk and any occurrence of serious harm to subjects and others shall be reported promptly to the IRB.

Your study has been approved for a period of 12 months. If your project continues for more than one year, you are required to provide a Continuing Status Report to the UNF IRB prior to **03/21/2011** if your study will be continuing past 04/20/2011. *We suggest you submit your status report 11 months from the date of your approval date as noted above to allow time for review and processing.*

As you may know, **CITI Course Completion Reports are valid for 3 years.** Your completion report is valid through 09/10/2012. If your completion report expires soon please take CITI's refresher course. Once you complete all of the CITI modules a completion report will be emailed to our office. For faster file updating purposes, however, please notify this office when you complete your CITI refresher course.

Should you have questions regarding your project or any other IRB issues, please contact the Office of Research and Sponsored Programs at 904.620.2455.

Thank you,

Research Integrity Staff

UNF IRB Number: 10-029
Approval Date: 4-21-10
Revision Date:

VITA

Lisa A. Jamba has a Bachelor of Science degree from the University of Florida in both Mathematics and Statistics and a Master of Arts in Education degree from the University of Florida in Higher Education. She expects to receive a Master of Science in Computer and Information Sciences from the University of North Florida in April 2011. Dr. Layne Wallace of the University of North Florida is serving as Ms. Jamba's thesis advisor.

Ms. Jamba has worked for the University of North Florida for over 11 years. Her current position is as a Senior Instructor and Advisor in the School of Computing. She also currently provides training to the University's faculty and staff on technology tools and acts as the coordinator for a workflow tool designed to facilitate the curricular governance process.

Her research interests include human computer interaction, computing education, computational thinking, and broadening participation in computing.