USING TOUCH GESTURES TO RECORD AND RECOGNIZE EMOTIONS

by

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ABSTRACT

In this thesis, we explore how people use touchscreens to express emotional intensity, and whether these intensities can be understood by oneself later or by others. We conducted a four-week participatory-design activity to improve the design of JogChalker, a system that allows recreational runners to record their emotional state while running using touchscreen gestures. Results indicated a desire for more expressiveness when gestures are recorded. A controlled study was then conducted in a lab environment where we asked 26 participants to express a set of emotions mapped to predefined gestures, at range of different intensities. One week later, participants were asked to identify the emotional intensity visualized in animations made by themselves and by other participants. Results indicate that the choice of factors was impacted by the specific emotion, and the range and rate of increase of these factors varied by individual and by emotion. We discuss implications for developers of annotation systems and other touchscreen interfaces that wish to capture affect.

LIST OF ABBREVIATIONS USED

GEM	Graphics and Experiential Media
PCA	Principal Component Analysis
PD	Participatory Design
SVG	Support Vector Graphics

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CHAPTER 1 INTRODUCTION

1.1 Overview

In recent years, emotions and affect[1] have become important areas of research in human-computer-interaction. There are many researchers focusing on designing interactive systems that elicit and support emotions beyond facial and vocal channels [19] [22] [39] [48]. In particular, communicating thoughts and emotions through touch interaction is an area of research that opens up new design opportunities [8] [42].

Our hands are channels for expressing emotion. For example, an artist's brush on a canvas can create a lively painting, or a dancer's movements can express a passionate storyline. Nonverbal communication can often convey emotion more effectively than verbal communication [14]. Using gesture to record emotion could permit affective annotation of events and experiences in a manner that requires little attention and could be done when mobile: for example, a recreational runner could comment on songs on their playlist, parts of their route, or how they are feeling by gesturing on a touch screen [4]. Popular mobile applications such as Runkeeper, Runtastic, and Endomondo [27] track running data and let runners visualize and share their runs. Aside from freeform annotation at the end of a run, such applications don't currently provide a means of capturing the affective experience of a run. One way to do this is to define gestures that represent different emotions—a semicircle for happy, a flat line for bored, etc.—but by simply generating a symbol, this is less expressive than writing or speaking "I am

[1] "Affect is the experience of feeling or emotion. It is a key part of the process of an organism's interaction with stimuli. The word also refers sometimes to affect display, which is a facial, vocal, or gestural behavior that serves as an indicator of affect" [1]

happy". Instead, we might interpret emotion in how someone gestures on a touchscreen: in the amount of force used, the speed, the size of a gesture, etc. Since a gesture can be recorded, it can be replayed, giving an animation of the gesture as an expressive action. For example, the current Apple iOS "digital touch"[2] feature animates scribble playback as a playful, lightweight way to communicate. Such a feature would enable recreational runners to better choose the time, place, and circumstances of their leisure runs. Manual tracking tools like Moodmap [12] and Emotion Map [21] allow users to tag locations and times with emotions, and present these on a map. Typical widget-based interfaces can be difficult or impossible to use when physically active, however [35].

In this thesis, we primarily consider how people use touchscreens to express emotional intensity, and whether these intensities can be recognized by oneself at a later date or by others. We also present JogChalker, a system that allows recreational runners to capture their affective experience while running using touch gestures and visualize these gestures afterwards. A Participatory Design (PD) study was conducted to design the JogChalker system (a gesture capture application and a visualization interface). This was a collaborative study with a colleague who developed the visualization interface of the JogChalker system while I worked on modifying and refining existing applications to meet the requirements of the gesture capture application. I then conducted a controlled study to evaluate users' expressions and recognitions based on a set of gestures to express corresponding emotional states.

[2] iOS allows animated messages to be sent containing heartbeats, kisses, scribbles, and even annotated photos and videos [32]

1.2 Relationship to Other Work

The JogChalker system is in part the culmination of original contributions made by researchers at Dalhousie and elsewhere. Iyer's [23] 'DreamFit' system was part of the inspiration and initial proof of concept for JogChalker. DreamFit was not a single app but rather a series of small iOS apps and a recommended architectural design. An Arduino hardware prototype was developed at the University of Saskatchewan called e-health, which captured ECG and gait data using accelerometers. This was modified by Kuatsidzo at Dalhousie for the "Body Sonification" project in collaboration with artists at NSCAD [28]. Kuatsidzo developed an Android mobile capture application for body sonification which included capturing of biometrics using the e-health hardware alongside GPS, orientation data, and user-generated video annotations. Liu concurrently worked on an Android application that captured and recognized gestures on the touchscreen [30]. I worked on bringing these components together into a single application, which became JogChalker version 0. Informal testing was conducted with lab members who ran several times with the app, and based on the feedback I developed JogChalker version 1. Then we conducted the participatory design activity where my contribution was to identify modifications to the JogChalker capture application interface with the participants. Visualization interface design sessions were conducted concurrently by a research associate. After refining the capture interface based on the outcomes of the participatory design activity, I conducted a controlled study focused on capturing emotional intensities using touch gestures. The research associate conducted a separate study to analyze runners' ability to recall affective experiences represented by recorded gestures, using the visualization interface. The overall workflow is shown as a timeline graph (see Figure 1).

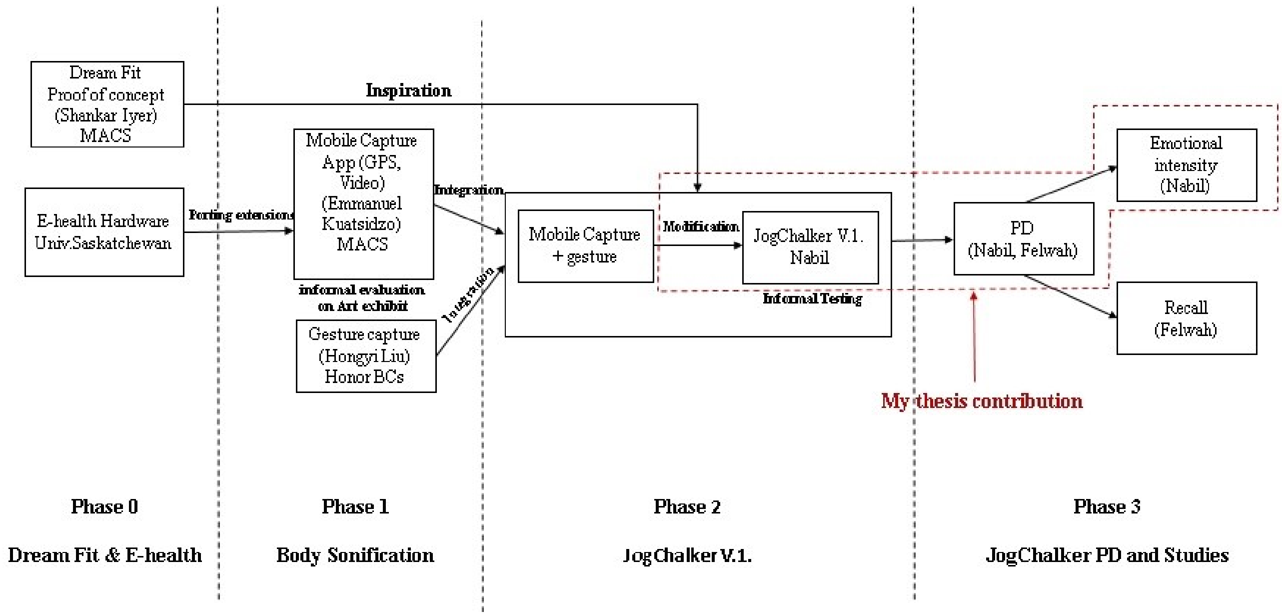


Figure 1 Overall workflow of the development process and evaluation of JogChalker

1.3 Thesis Contribution

This thesis work contributes in exploring the idea of using gesture to capture emotions. The thesis contributions are as follows:

Collaborative Research Contribution:

- Iterative design and development of a prototype gesture capture and visualization tool for recreational runners called JogChalker, which captures gestures representing emotional states.

Own Contribution:

- A controlled study examining how people use touchscreens to express emotional intensity, and whether these intensities can be understood by oneself at a later date or by others.

Thesis Roadmap

Chapter 2 covers the related work, where we consider exploring touch and universal emotions, how touch gesture technologies and micro expressions communicate emotions, and other methods to express emotions. Chapter 3 covers preliminary implementation and design details of the JogChalker capture application. Chapter 4 describes the participatory design study. In Chapter 5, the controlled study's design is presented, including the gesture capture and replay tool developed, the two study phases, and our analysis methodology. In Chapter 6, we discuss the overall findings from the controlled study. Chapter 7 is a discussion of our observations, generalizability, design implications and future work.

CHAPTER 2 BACKGROUND AND RELATED WORK

We present in this chapter related work to the topic of using touch gestures to express intense emotions and understand those emotions with proper visualization. We first introduce micro expression and discuss how touch is driven to express and experience social emotions. We then review gestures as a way of expression on touchscreen interfaces, and how these gestures can be used to express emotions. Finally, we examine how multivariate data can be visualized to display the expressiveness of gestures.

2.1 Micro expressions

Micro expressions were discovered by Haggard and Isaacs in 1966, while conducting physiotherapy interviews [17]. Such expressions last for microseconds and do not necessarily match the overall facial expressions that reflect specific emotional situations. It is believed that micro expressions represent the true emotional status that a person can experience [10]. Ekman [10] identified seven micro expressions (Surprise, Happiness, Fear, Anger, Sadness, Disgust, and Contempt) which are well known and agreed upon in the scientific community. Our work focused on identifying ways how a person can express an emotion. For this reason, we needed a universal standard expression set which led us to consider the micro expressions in the initial part of our research.

2.2 Touch and social emotions

There is a strong connection between touch and social emotions, where the nature of human touch can vary based on the emotional state that they are experiencing [7] [42]

[46]. To understand the emotions that drive touch, Rantala et al. [42] conducted a study where a sender and receiver communicated emotional intentions (unpleasant, pleasant, relaxed or aroused) using a tactile device (see Figure 2) with four sensors via squeeze and finger touch. These stimulations were rated by the sender and receiver in a fixed scale. Their results suggest that finger touch on the device was effective in communicating pleasant and relaxed emotional intentions where squeeze was better at communicating unpleasant and aroused intentions. The tactile communication taking place led people to feel emotional engagement. Our work focuses on communicating through finger touch to express emotions, but these are not directed toward another person, nor "experienced" as

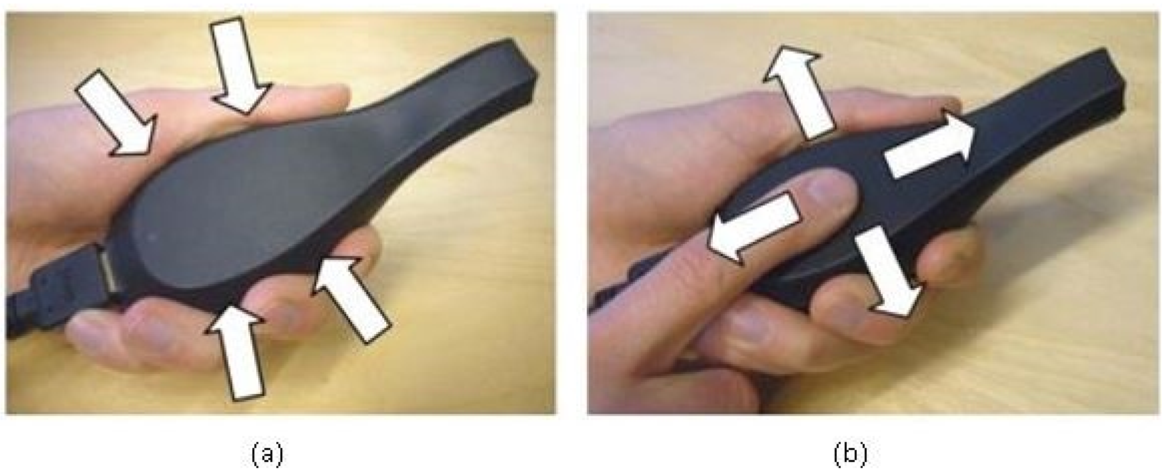


Figure 2 Tactile device to express touch gestures of (a) squeeze and (b) finger touch [43]

tactile communication by another, so it is not expected (though unclear) that the same visceral emotional engagement will be experienced.

Bailenson et al. [3] worked on haptic stimuli to express emotions. Their findings suggest that people are able to express and recognize emotions with the help of a force feedback device that simulated a handshake. Smith and MacLean [48] confirmed strangers' ability to express and recognize each other's specific emotions using a purely haptic link. Similarly, Schirmer et al. [45] conducted a comparative study with touch and voice to convey a physical sensation towards an individual. Their results suggested that 'touch' sensitizes ongoing cognitive and emotional processes.

According to Jung et al. [24], touch is a behavior that can be used in social communication. Such communication requires a medium and techniques to transfer interactions to other parties. They introduced 14 social gestures i.e., pat, scratch, slap, stroke, tickle etc. in three different levels (gentle, normal, and rough) and asked participants to perform each gesture on a sensor grid. They used 2 algorithms (Bayesian classifiers and Support Vector Machines) to recognize the level of each gesture. Results show that recognition accuracy is 54% for Bayesian classifiers and 53% for the SVMs. Our work concentrates on understanding how a gesture can be manipulated via touch to express an emotion at different intensity levels and if these intensities are easily identifiable from the gestures. We also consider three discrete intensity levels (mild, moderate, and extreme) for each emotion. Rather than consider machine classification, we ask whether the intensities can be recognized by other people and/or oneself.

2.3 Human to human touch communication

According to Hertenstein et al. [20], 'touch' as a method to communicate emotions has not received enough attention compared to facial expressions and voice. Their study showed that 'touch' can be used to communicate a set of emotions such as anger, fear, happiness, sadness, disgust, love, gratitude, and sympathy. They asked each participant to touch a stranger's forearm to convey one of the emotions, which then had to be decoded by the other person. Their data suggests that the intended emotions are recognized as accurately (50% to 70%) as decoding emotions from facial expressions and vocal tone. This also supports the finding of Guerrero et al. [16] that 65% of social emotions are delivered through nonverbal methods.

Park et al. [39] explored touch interaction during phone conversations for long-distance relationships. They developed POKE, a device that enables the callers to share touches during the conversation. During the study, they asked the users to use their index finger as a means of touch input because index finger is the most stable and can be moved naturally. The pressure intensity, frequency, pattern, and shaking that were transmitted through index finger movements were passed onto the other person's cheek through the air inflation patterns of POKE's front surface. Their findings suggest that sharing a tactile vocabulary over distance was useful for expressing and understanding emotions. Also, for positive emotions (i.e., "I love you") weak touches were delivered, while negative emotions (i.e., "It's annoying") were often expressed through hard, fast, and continuous touches.

Our work does not examine technologically-mediated human to human touch; instead we consider this work as a source of inspiration for developing a set of touch-interactions to express emotion. More generally, since touch is a known channel for expressing emotion (as explored primarily in human to human touch) and gesture is a known medium of expressivity, we are interested in whether touchscreen gesture is a suitable channel for expressing emotion.

2.4 Expressing emotion using gesture and touch interfaces

Gestures represent a form of nonverbal communication that has become very prevalent in HCI research and practice [25]. While much of this research has focused on ways of making computer interaction more efficient [32] or precise [43], a number of researchers have considered how gestures can be used to express emotions.

Gaver [15] has explored devices and systems that can be used to convey emotions and found that communicating emotions effectively relies on the dynamics (novel sensors, interaction techniques, and increased engagement) of using the device.

Pirzadeh et al. [40] proposed a set of multi-touch gestures (see Figure 3) to represent facial expressions related to human emotions. These gestures were identified through a qualitative study to explore how mobile users express emotions while instant messaging in three different scenarios (sad, happy, and angry).

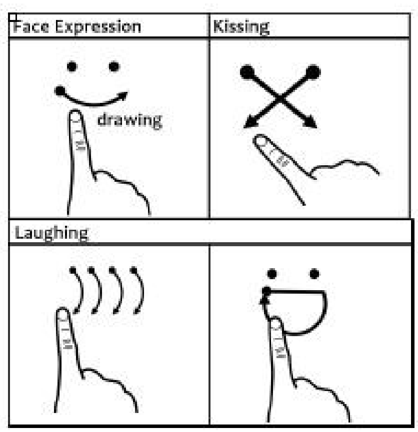


Figure 3 Multi-touch gestures for facial expression [41]

Camurri et. al. [5] focused on modeling affect and expressiveness of gesture interaction in social communication. They proposed a framework for communicating expressiveness and affect in multimodal interactive systems, specifically focused on understanding expressive cues of music from user movement.

Mullenbach et al. [36] asked users to touch a variable friction surface on tablets to convey emotional information (e.g., share feelings between couples). They concluded that users readily associate haptics with emotional expression.

Our work concentrates on capturing affect and ability to understand the expressiveness of captured emotions through animated gestures. Using animations to convey touch-based emotions is underexplored and our focus was to see whether haptics can be always used or does animations provide a better visualization in understanding emotional intensity.

Some research in handwriting analysis suggests that different factors/features such as size, pressure, zone/word spacing, and angle may be a way to identify user behavior patterns [6] [33] [41]. Haines et. al [18] proposed an algorithm where they used learned parameters for spacing, line thickness, and pressure to produce novel images of handwriting that could imitate a specific author's pen-on-paper handwriting style. Yu et. al [54] examined handwriting using stroke-level features and their findings show that writing pressure and velocity information are very good indicators of cognitive load to improve task quality and performance. Our work considers identifying user drawing patterns to express emotional intensity. We used some of the same factors i.e., size, pressure, speed, position, and thickness to understand how users express emotional intensity through gestures using these factors.

2.5 Use of emotion-related haptic interaction in HCI

While touch interfaces are now ubiquitous, a lot of research remains within the context of HCI [9] [13] regarding touch. Communication with digital devices that utilize touch interactive screens as the input method can effectively accommodate touch dimensions to express commands at different levels [55].

Flagg et al. [13] suggested that touch has different dimensions such as speed, length, pressure level, contact area and position that can be translated into one unique sense of emotion. They developed a fur-based touch sensor with the integration of a fabric location/pressure sensor and used this interface to collect time-series data. They asked each participant to express a set of 9 key emotional gestures i.e. stroke, scratch, tickle, squeeze, pat, rub, pull, contact without movement, and no touch. They also explored machine learning analysis to identify gesture recognition accuracy using different factors such as speed, length, pressure level, contact area and position. Results show that their proposed model could recognize gestures with 86% accuracy when applied to the combined set of all participants. Our work uses the five dimensions considered in Flag et al.'s research (speed, length, pressure, contact area/width, and position) as a means to express emotional intensity, rather than to define and recognize "emotional gestures". The specific emotions themselves are encoded as different gestures in our work.

Liu et al. [31] have explored different tangible communication methods that can be used to communicate emotions. This was achieved by asking participants to use a gestural interaction to express/communicate emotional patterns (positive intense, positive calm, negative intense, negative calm) at different intensities (slight, moderate and heavy) on a balloon (see Figure 4). Their participants made haptic gestures by touching the balloon to

Figure 4 Balloon used for observing gestural interaction [32]

express the same emotion. Their results show that gestures varied significantly across the participants. An emotion communication device called EMO was developed based on the results. The device consisted of a sender with multiple sensors and the receiver part vibrated based on the input provided. Both parts were connected through the Internet.

Obrist et al. [37] explored the communication of four emotions (happy, sad, excited, afraid) through a haptic system (see Figure 5) that uses tactile stimulation. These haptic expressions were made by one group of participants to express the four emotions. These expressions were reviewed and validated by another two groups of participants. Their

Figure 5 The UltraHaptics system used in the study, where participants positioned their left hand above the array [38]

findings provide an initial basis for exploring the emotional design space for haptics in mid-air.

2.6 Visualizing Gestures and Multivariate Data

According to Shenas et al. [47], visualizing information from raw data is an open research question and colour is perhaps the universal way to visualize information of a particular data variable at a given time. Visualizing multivariate data is still an ongoing research and both Shenas et al. [47] and Urness et al. [51] suggested that 'texture' can be applied with colour as another dimension to visualize two-dimensional data. Kirby et al. [26] visualized multivalued data i.e., depth of water flow using a single colour (bright colour to display deep water region and light colour for shallow water region) and the direction of flow using arrow symbols (‘>’).

Touchscreen gestures are a form of multivariate data if broken into their constituent parts (pressure, length, etc.). Vatavu et al. [52] introduced ‘gesture heatmaps’, a gesture visualization and analysis technique that analyzes gestures by using colour representation and considers multiple factors across the path of these gestures (see Figure 6). Their work was focused to have a better understanding of users’ gesture articulation patterns and encourage researchers to explore gesture heatmaps to uncover new findings about users’

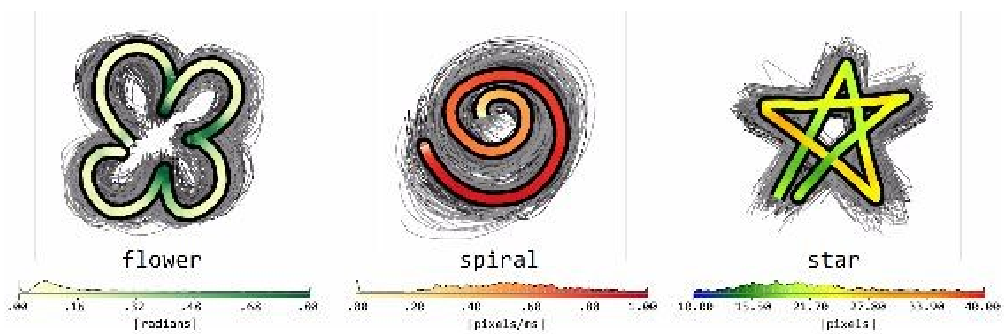


Figure 6 Gesture heatmap examples illustrating user variation [53]

gesture behavior, design better gesture sets, and to develop more accurate recognizers. Their findings demonstrate heatmaps’ capabilities to characterize users’ gesture articulation patterns under various conditions, e.g., finger versus pen gestures, and also help understand users’ subjective perceptions of gesture commands, such as why some gestures are perceived easier to execute than others.

Our gesture visualization concerns visualizing multiple data variables from each gesture i.e., touchscreen pressure, gesture size, width, and drawing speed. However, our visualization only used changing colours to provide each gesture path a unique ‘texture’.

We used colour to visualize pressure, display the gesture as a continuous line as it was drawn, adjust the thickness of the line to show the changing width of the finger-surface used to draw that gesture, and use a continuous animation to show the exact speed (and changes in speed) of the gesture being drawn.

2.7 Participatory Design

We conducted a participatory design study to improve the design of our JogChalker version 1 (gesture application and the visualization interface). Spinuzzi et al [49] looked into the characteristic of a participatory design and suggested that participatory design is all about designing along with the user, and evaluating results through workshop and prototype until both are satisfied with the end product. Kuo et al. [29] also suggested that participatory design is a method where the designer of a system is no longer engaged in one-sided designing. This process allows the users of a system to contribute their ideas and suggestions to make the development cycle more interactive.

CHAPTER 3 PRELIMINARY IMPLEMENTATION AND DESIGN

In this chapter, we motivate and describe the design and implementation of the gesture capture application developed in this research. We further elaborate how the capture application was modified from existing applications and describe the basic architecture of the system. Finally, we discuss modifications after initial testing.

3.1 Motivation

The main focus of this thesis was to explore the idea of using gesture to capture emotions. We explored Iyer's [23] work where he developed 'Dreamfit', a framework for personal fitness information management. The framework focused on the development of applications for runners in which they can concentrate on their running, without requiring excessive amounts of information to be input, while still allowing flexibility in the data captured and in the interpretation of that data. Applications using this framework can make use of context-based information and gesture-based user input. These include, for example, location data from GPS and the touch co-ordinates on the user's smart phone screen. Our work did not build on Iyer's architectural recommendations. However, the aspect of capturing gestures became an important aspect in our research as we were interested in understanding user experience.

We also used the data-logging feature of Kuatsidzo's [28] 'BodySonification' application where he developed an Android mobile application that enabled wireless capture and storage of stream data from a custom wearable device and the wireless retransmission of the data to a server. The application allowed the users to record and store short high quality videos concurrently alongside the biometric data collection process. It also stored the user's location and orientation information that focuses capturing, processing and creatively re-presenting the affective experience of the mobile body in urban spaces in an artistic way.

Liu [30] integrated his gesture capture application with Kuatsidzo's [28] 'BodySonification' application for Android devices that tracked biometric and positional data. His application recorded and recognized four basic gestures (e.g. circle, square, figure 8, triangle) which were categorized on the device in advance. The application also recorded a range of low-level attributes including time spent to draw, gesture path, touch area, and pressure. All the gestures were stored as static SVG documents. Our work concentrated on using the aspect of this gesture capture application that Liu [30] integrated.

3.2 Initial Implementation

Our initial application development work concentrated on extending the gesture drawing feature of the existing integrated application developed by Liu [28]. As the gestures were saved as static SVG documents we increased the clarity of the visualization by adding color and animation.

We added the feature of automatically saving each continuous gesture after it was drawn. All related gesture data (coordinates of the drawn gesture, pressure value in decimal at each point, in-between timestamp from one point to the next) were logged in a single output file and locally stored on the android device. We used these data and applied SVG built-in functions with appropriate parameters to save each image with a continuous animated image. This was done to provide a better visualization of the drawn gestures to the users. The animation feature of each gesture was the first step in order to understand the expressiveness of how an individual may express a particular emotion. Initially, the gestures were animated using a single colour (i.e., red colour). We applied colour spectrum (see Figure 7) to visualize the change of pressure while drawing each gestures to express different emotions. Each animated gesture replayed in a changing colour according to the colour spectrum to represent different pressure levels while drawing the touch gesture. We used android's built-in pressure sensor to get the pressure values ranging from 0 to 1 and it generated a different decimal number for pressure value based on the nature of the press on the device. The colour ranged from green to red where dark green referred to lowest pressure (a decimal value of 0) and dark red as highest pressure (a decimal value of 1). This helped us to create a continuously coloured animated gesture.

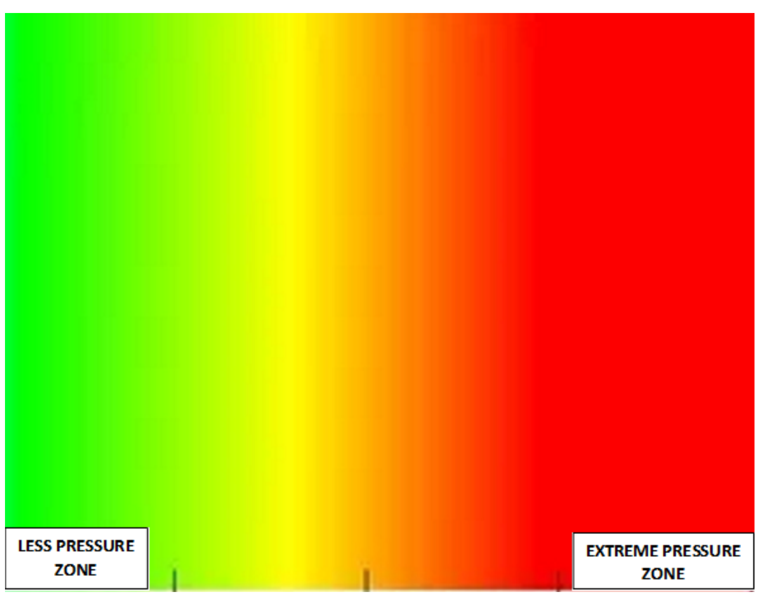


Figure 7 Colour spectrum to specify pressure range: left-side (green) as less pressure zone, and right-side (red) as extreme pressure zone

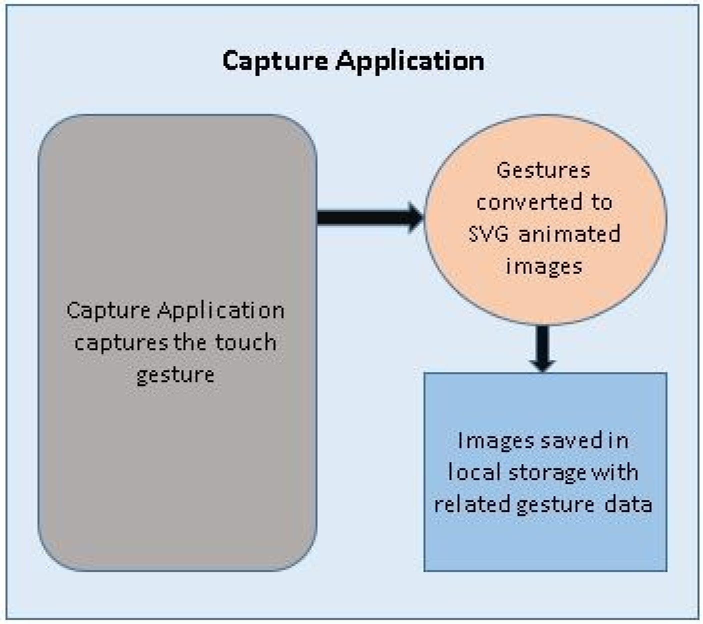


Figure 8 Basic architecture of the capture application

We provided an extended colour at each end so that the users have an easier understanding of the two extreme pressure zones. Our application was installed in an android mobile device for our experiment that was pressure-sensitive. Figure 8 shows the basic architecture of the capture application. Here, the capture application senses the touch gesture and based on the relevant data converts the gesture to an SVG animated image file. This file is stored locally on the device.

3.3 Informal Testing

The application was tested by 2 colleagues from our research lab three times and they used the application during their runs. The application malfunctioned while one colleague tried to draw multiple gestures in quick succession. We figured out that the application required some time in processing the drawn gesture. So, we made the screen inactive until each gesture was processed and stored locally as an SVG animated file.

The other colleague suggested that as the application's touch sensing surface was smaller than the device's screen resolution it was sometimes difficult to draw a gesture on the bottom section of the device screen. The colleague also suggested that a reminder notification from the application would be a nice addition to keep the runner motivated to draw gestures while running. Based on the feedback, we changed the screen resolution of our application and made it full screen to make it convenient for the runners. As this was not a natural process for recreational runners to make gestures on a touchscreen while running, we also included a reminder by vibrating the device that was used to draw gestures at a 10-minute interval during each run.

3.4 Visualization Interface Concepts

At the same time, lab colleagues considered potential visualization designs for presenting captured gestures alongside typical running data (GPS, biometric data). After considering a few initial concepts, a colleague developed a first prototype using MapBox, a JavaScript geospatial visualization library. Prior to further development and integration with the capture application, we designed and conducted a series of participatory design sessions with recreational runners, as discussed in the next chapter.

CHAPTER 4 PARTICIPATORY DESIGN AND SECONDARY IMPLEMENTATION

We conducted a four-week participatory design (PD) study to get feedback from recreational runners to improve the design and functionalities of JogChalker, a system that allows runners to capture their affective experience while running using touch gestures and visualize them at a later period.

4.1 Prototype

Our JogChalker prototype consists of a capture application and a visualization tool. The capture application is written in Java and run on Android devices (see Figure 9(a)), and provides a full screen gesture capture interface. A yellow trace line shows a gesture as it is being made, and it is recorded in real time. When an onscreen finger-touch is sensed by the device's screen, the application displays a yellow dot on the screen. It continues to create a yellow trace line based on the movement of the finger. If the finger is lifted from the screen, the application records the full path of the drawn gesture as it was made. Each

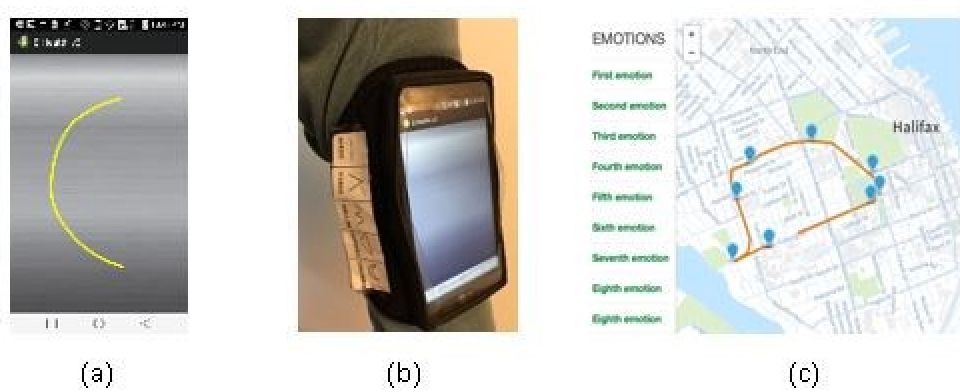


Figure 9 (a) mobile screen for gesture application (b) armband with gesture list (c) initial map-based visualization [4] gesture has a start point (when the finger touches the screen) and end point (when the finger is removed from the screen). Furthermore, all the touch points' in-between timestamps are recorded. These timestamps are used to animate the gesture at the same speed as it was drawn. We used a standard Android gesture recognition library that classifies the gesture once completed.

In addition to the time and location in which a gesture is made, we record the traversal of the drawn gesture in terms of elapsed time and screen coordinates, as well as the width of the touch area and the device pressure (if supported by the hardware) throughout the gesture. Using this we generate an SVG animation so that the gesture can be replayed on the visualization interface. From the low level data, a number of higher-level factors of the gesture can be determined, including repetition, total area, average speed, and total time taken.

Two researchers from our lab informally tested the capture application. They went out for a run for 25- 30 minutes and expressed their feelings by gesturing on the screen. Initial testing showed that the researchers were drawing gestures based on something they saw on their running route. Some of these drawings were random shapes and objects i.e., clouds, kitten, flowers that they saw during their run. We associated the gestures to the running scenario (adding the geo-coordinates of the place where the gestures were drawn) and concentrated on selecting some of the emotions that runners generally feel during their runs. Based on the two researchers' suggestions and mental states that they felt during their run, we chose five running-related emotional states i.e., bored, tired, mellow, euphoric, and exhilarated. Furthermore, we developed simple candidate gestures related to each emotional states for evaluation (see Figure 9(b)).

A first prototype of JogChalker's visualization interface was written in JavaScript, and was built using Mapbox Studio (see Figure 9(c)). The Scalable Vector Graphics (SVG) gesture image was merged with the route data based on the timestamp of capturing SVG image. the initial prototype of the visualization was divided into two sections. The first section displayed a single running route with teardrop markers where the emotion occurred, and the second section presented a list of hyperlinks to the gestural annotations made during the run. Clicking a marker or list item would display the associated gesture as a static image.

4.2 Participatory Design Study

We employed a participatory design approach with recreational runners. We conducted a pilot study where we asked two researchers in our lab with consent to go out for a short run (5 – 10 minutes) with the proposed capture application and asked them to draw gestures based on their feelings at different locations. We did not provide them any specific suggestions for gestures but suggested them with some related feelings i.e., tired, bored, mellow, exhilarated, and euphoric to consider while running. After pilot testing with two lab colleagues we arrived at the methodology shown in Table 1 (Appendix D), and detailed below.

Session	Method			
	Application design	Duration	Visualization design	Duration
1	Sketching (pen & paper)	15 mins	Sketching (pen & paper), paper widgets	30 mins
2	Sketching (pen & paper), moqups, paper widgets	30 mins	Sketching (pen & paper), paper widgets	30 mins
3	Group design (Sketching & Paper Prototyping)			1hr + 1hr
4	Group session – Brainstorming (Phase 1 & 2)			40 mins + 20 mins

Table 1: Methodology for all the sessions

4.2.1 Running with the Capture Application

We recruited 4 recreational runners, who each participated in 4 design sessions (Table 1) over a 4-week period. Each session was divided into two parts – capture interface design and visualization interface design. After signing the consent form (Appendix B1), each participant was provided training with the application and they were asked to draw all the

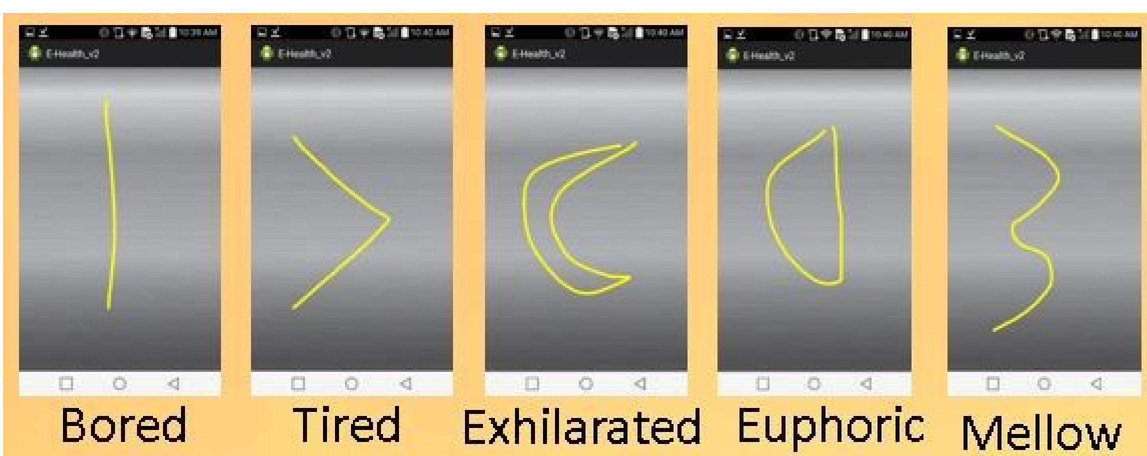
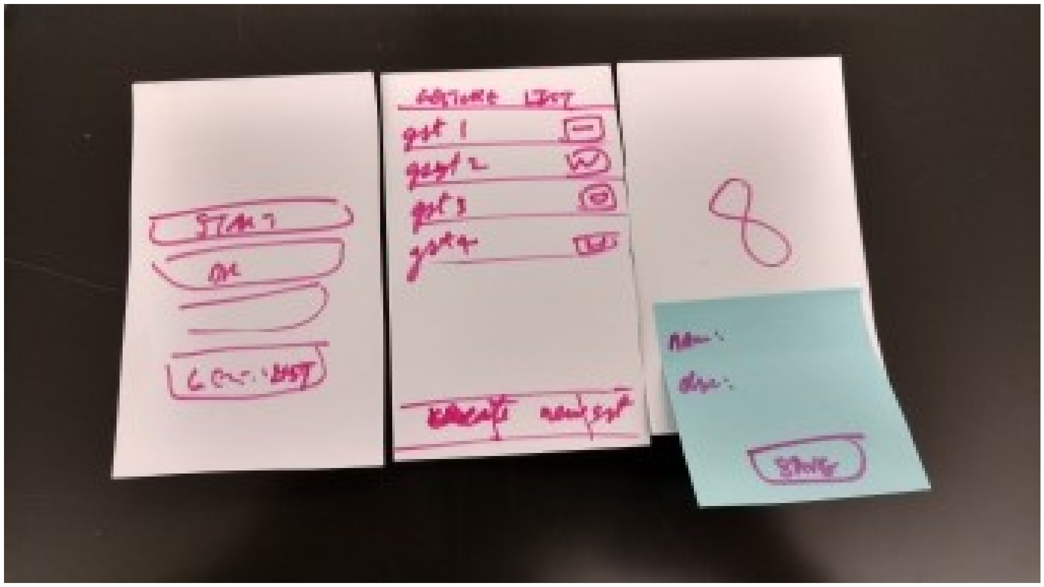


Figure 10 Sample gestures for the 5 running related emotional states

5 gestures (bored, mellow, tired, euphoric, and exhilarated) (see Figure 10) once on the application screen. Then the Android smartphone (pressure-sensitive) was strapped on their arm using an armband. After strapping the smartphone on the arm, participants were again asked to draw a gesture of their choice from the gesture list to test their comfort with the setting. Assessing all these, each participant went for a run in their familiar route for 30-60 mins using the capture tool immediately prior to each session. A Mio heart rate wristband was attached on their arm to record heartrate during each run. Gestures were displayed on the side of the armband for quick reference (Figure 9(b)). Since participants were not used to recording emotions while running, the mobile device would vibrate if no gesture was recorded over a 10-minute interval; otherwise participants were not prompted to record gestures. The Runkeeper application was also launched on the phone, and we preloaded the phone with a personal playlist if they preferred to listen to music while running. Participants also wore a GoPro camera while running. This was to generate a video stream that we provided as a potential element to include in the visualization interface, and to get a record of whether they slowed down or stopped, and whether they looked at the screen when making a gesture.

4.2.2 Design Sessions

The first two PD sessions were done individually and the last two sessions were done as a group. In session 1, participants sketched potential modifications to the capture pplication using pen, paper, and post-its. Figure 11(a) shows all the features suggested for the capture application by our participants.

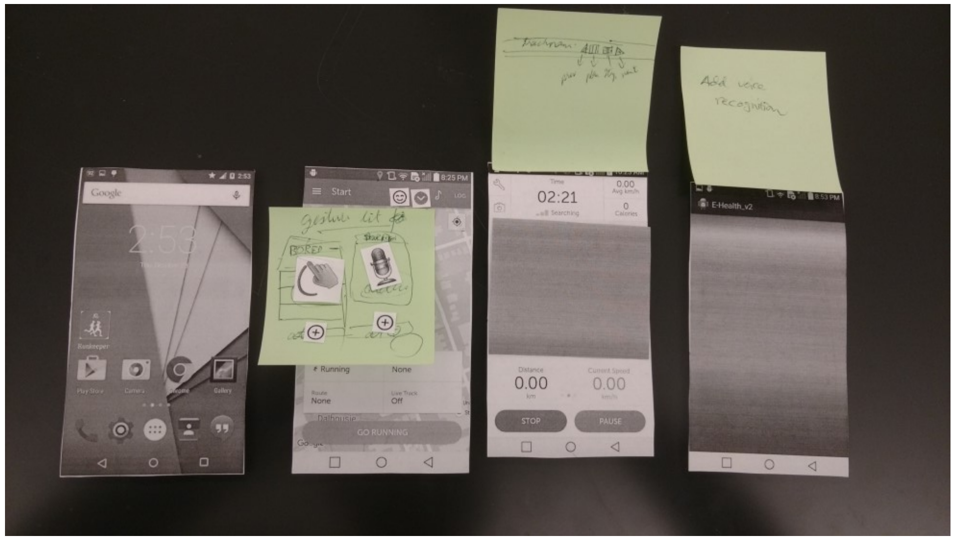


(a)

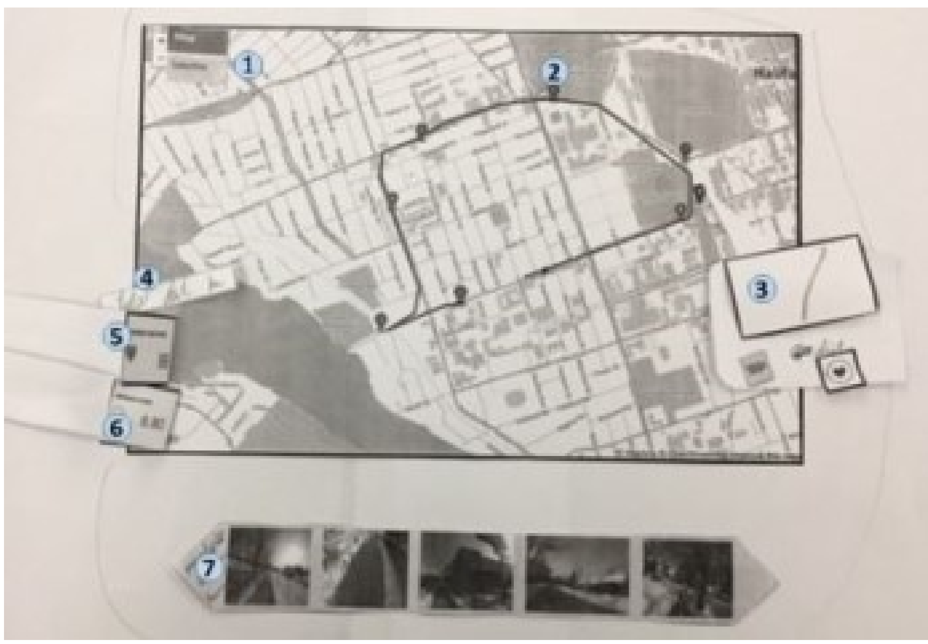
(b)

Figure 11 Sample visualizations from session 1(a) capture application: a button is placed named 'Gesture List' on the bottom of the first mockup screen, after it's clicked, the second screen will show a list of gestures (gesture name and a small icon of that gesture's shape) and clicking on the 'Create new gesture' will open a new screen area for drawing the gesture and provide a name to save that gesture. (b) visualization interface: a map to show the running route, an image of the location where the gesture was captured, display the heartbeat, alleviation, and speed during the run.

and the GoPro video feed. They were provided with pen, paper, and a set of paper widgets (including elements from the two visualizations and others not presented on either visualization including video, music, and weather data) and sketched a single visualization interface that would allow them to create a gesture list and store the captured gestures with other data they deemed relevant for visualizing their experience (see Figure 11(b)). To ensure the reliability of the sensor data we used Runkeeper's official website to collect and then stored each participant's running data.with consent. In session 2, we expanded the ideas of the sketching from the design session 1 and used current Runkeeper interface as a base theme to integrate our touch gesture application. The main focus of session 2 was to generate ideas on what options were necessary for each individual to capture their affective experience during their run. Participants were provided mockups, pen, papers, and post-its and they tried to integrate the gesture capture interface inside the Runkeeper application. Furthermore, the goal was to try to design a low-attention interface that will allow the users to record their emotion and collect all the related data. Our participants used the same tools from design session 1, and integrated the gesture capture application into Runkeeper (see Figure 12(a)), and work on their visualization design after viewing those made by the other runners (see Figure 12(b)). The last two sessions were conducted as a group.



(a)



(b)

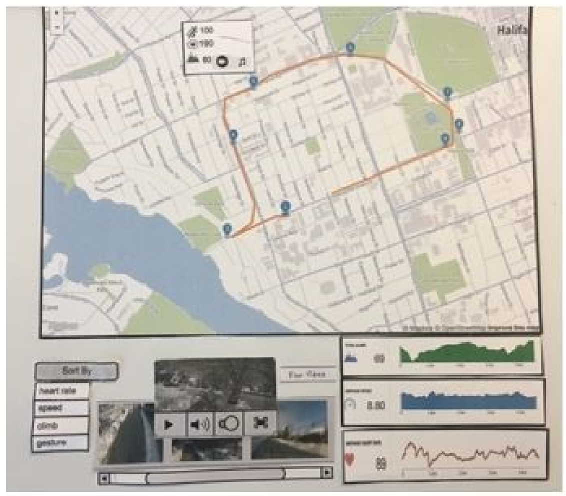
Figure 12 Sample visualization from session 2 (a) capture application: after starting the application, the screen shows 2 vertical sections, touch gesture list and voice recordings list. Clicking the touch button will show a blank area to draw gestures, and the top will have a music control panel (pause, next, previous music selection), double clicking the blank touch area will open the touch area in full screen view (b) visualization interface: (1) choosing map or satellite view, (2) each point where a gesture was made (3) an animated gesture of the emotion in that point (4) speed (5) heartrate (6) elevation (7) images of each point where gestures were made during the run [4]

In Session 3, the group met at the Mona Campbell building in a controlled lab environment (see Figure 13). They presented and discussed their own and other member's designs in sequence. Discussion was focused on the positive and negative aspects of keeping or removing a set of proposed features. Our participants were asked to identify all the features that they felt must be provided in the final version of the application. They were also asked to consider the tradeoffs between functionality and

Figure 13 Environmental settings for the group design session 3

simplicity. As a group, they were asked to sketch out the basic interface using pen and paper and afterwards they worked together to create a single integrated gesture capture design mockup (see Figure 14(a)), and a single affective experience visualization interface (see Figure 14(b)). After an initial discussion among our participants to identify

(a)



(b)

Figure 14: Session 3 designs – (a) Gesture capture design. (b) Visualization interface. [4]

features for designing the integrated capture application, we gave them a list of scenarios to consider for the design:

1. running on a rainy day
2. running on a cold day with your gloves on
3. running with a group of people
4. running in a race
5. running on a wooded trail
6. running in a busy downtown area

7. running in a new town
8. leisure cycling
9. going for a walk

We provided these scenarios to assist our participants to think in varying situations into design consideration and our participants suggested that the application should have all necessary features (a customized list to view and edit gestures, audio, notes; an option to add music navigation) and some optional features based on some of the scenarios. For example, based on their suggestions for a rainy or a cold day, users should be able to use a voice recorder rather than drawing on the screen. Similarly, they suggested that touch gestures are easier to use in places where runners are in a group, or running in a busy downtown area.

Session 4 was conducted in two phases in the style of a Future Technology Workshop (FTW) [53]. The goal of the FTW was to have an overview of user requirements during running, what type of data can be collected and how can we use a future technology to collect it. It also covered what type of visualization can be used to effectively tell a user's run history and how to improve insights and decision-making for later runs. In the first phase, the group brainstormed about alternative methods that recreational runners could use to capture a variety of data from their affective experience while running. These methods were focused on technology that might exist in near future. The second phase was more focused in brainstorming potential ideas to better understand the running related data with the help of visualization.

4.3 Outcomes

We describe the products from each session from the PD study in detail for gesture capture, and summarize the products generated for visualization. We then present the overall findings for the capture application session and summarize visualization interface suggestions.

4.3.1 Session 1: Initial Design

It took sometime for our participants to distinguish between exhilarated and euphoric. Other than that, all the gestures were easy to draw and they didn't give much thought of those gestures while drawing those gestures during their runs.

In session 1, our PD participants initially thought of creating an application design that will allow them to draw a gesture and have a list of gestures.

P1, P2 and P4 suggested to add voice recognition to the application. They felt the application might be able to identify an emotion based on the user's voice (e.g., if the person is bored or excited, it usually appears in the voice). P1 pointed out that while running if it was tiring, it will be easier just to draw a gesture rather than speaking because of breathlessness.

A number of minor interface features were also proposed. Both P3 and P4 suggested having a '+' button on the main application interface to open the gesture screen. P3 imagined a visual list of currently-recognized gestures. P2 also mentioned battery life might be a concern for logging and tracking, especially during long runs.

For visualization, P1 and P2 preferred a simple map with all related data visible in one interface while the other two participants preferred a simple map showing the emotion annotation only but the related data to become visible after a selection interaction.

4.3.2 Session 2: Refinement After Initial Session

Participants were interested to have an additional option to create their own custom gestures. In session 2, they integrated the capture application with the existing Runkeeper application.

P2 and P3 suggested to have a list of gestures prepared before each run on the application. They also suggested the application would notify them to prepare their list on the night before they go for running. They also suggested that the application would have multiple lists and the user will choose a list before going out for a run.

P1 focused on having an application that will recognize voice and change the songs accordingly. Furthermore, it would be also interesting to change songs using a gesture (e.g., a bored gesture that will start playing a melodious song).

P4 suggested using voice instead of drawing gestures. According to P4's notion, runners do not need to stop as P4 had to stop to draw each gesture. Furthermore, the application should find an ideal route after each 20 runs and should avoid selecting routes which has more emotions such as "bored".

For visualization, participants added the option of burned calories, and distance covered during each point of the run. Furthermore, one participant suggested to display the heartrate and music on the pop-up that at the point where it displays the animated gesture.

4.3.3 Session 3: Group Design Session

All participants collaboratively discussed to have a capture application interface where touch mode will be always on, have the functionality of a voice mode and a single emotion button to display a pop-up window with a list of gestures, voice commands and notes. The capture application will also give them the flexibility to manipulate existing gestures or voice commands.

As P1 suggested to be able to draw gestures to change the music, P3 contradicted that it should require much task to sort all the songs because runners will not like a certain set of songs and they may require to add a new a song list before going for each run.

All the participants agreed to have the option of small bar on the top of the capture application to change the music.

P2 proposed the idea of recording notes during the run with the help of the application to capture affective experience. All the participants thought it would be a great addition which will allow them to remember the surrounding environment better at that time during the run.

All participants finally agreed that keeping gestures should be helpful in case of specific scenario (e.g., running on a crowded street). Though P2 and P3 drew a lot of gestures during their they agreed that if a person will be using the same capture application for some duration then they will become more used to it and will draw gestures when they will feel to do so.

For visualization, all participants agreed to have a large map that show the emotion's location and the runner's path; if you click on the landmarker of the emotion, a small window pops up to display biometric data for that emotion, including speed, heartrate and climb. The pop-up windows also have icons for the music and video, which should not cover the path. There will be a slide-bar under the map so if you click on a video icon, the video related to the emotion will appear bigger and begin to play.

4.3.4 Session 4: Future Technology Workshop

In the FTW session, participants identified potential data (e.g., brainwave signals, weather data, runners weight) that are important to improve the current technology and develop a better tool keeping these in consideration. All the participants agreed with the idea of having a nano-chip to capture emotion automatically and only concentrate on the run. They also suggested based on current technology it would be nice to have an artificial intelligence system in the house which will update the runners daily about their routine and food consumption.

For visualization, our participants preferred to see a 3D display of their body structure showing their weight, body fat and time suggestions for the next run to keep them fit and also enjoy the run.

4.3.5 Overall

To summarize the overall findings from our PD sessions, recorded emotions varied among our PD participants. 1 participant drew gestures for mellow, exhilarated and bored, 3 others used tired and mellow mainly. We annotated designs and identified themes (Table 2) that emerged in the designs and participant comments across the 4 design sessions. Our participants discussed about the compatibility of different features in the application and came to an agreement of keeping both touch mode and voice mode. All of them preferred to keep the touch mode always on. They also suggested of keeping

		Session 1				Session 2				Session 3
Participant ID		P1	P2	P3	P4	P1	P2	P3	P4	Group session
Themes	Buttons	-	1	0	2,3	0,1	5	2	2	4
	Touch mode	7	6	6	6	7	6	6	6	6
	Voice record mode	-	-	-	-	7	6	6	6,7	6,7
	Touch Gesture List	-	-	2	2	-	-	8	10	8, 13
	Voice commands	-	-	-	-	-	-	-	11	9
	Notes	-	-	-	-	-	12	-	-	12

Table 2: Components used in each of the 3 capture application design sessions.
0 – Touch gesture button, **1** – Voice record button, **2** – Gesture list button, **3** – Draw gesture button, **4** – Emotion button to add/edit gestures, **5** – 4 separate buttons (W/O gesture & voice, with gesture + W/O voice, W/O gesture + with voice, with gesture & voice), **6** – Capture emotion, **7** – Change songs, **8** – Dialog box to show list of gestures (Touch mode is on by default), **9** – Dropdown list to show all gestures, **10** – Dropdown list to show all voice commands, **11** – Voice record notes while running, **12** – Single dialog box to view and edit list of touch gestures, voice commands and notes as subsections.

an emotion button that will open a pop-up window where they can view, add, edit, and delete gestures at their convenience.

Participants liked that gesture capture was automatic. They found recording gestures tricky when in full run, but didn’t mind slowing down to do so. All participants wanted to define their own gestures, and found it difficult to distinguish between euphoric and exhilarated. They all wanted to be able to record voice annotations, instead of or in addition to gestures. Integration with Runkeeper was refined toward a simple interface to enter recording modes, and a screen for reviewing and deleting annotations on the mobile (see Figure 14(a)). The group also suggested that recording an emotion could immediately trigger a change in music playlist. Our participants did not mention discomfort with the armband but did discuss using a smart watch as an alternative.

Visualization interface designs maintained a simple map-based run plot; most debate centered around whether data other than route and gesture location should always be visible or only after a selection interaction. When a gesture location is selected in the group design, a synchronized video stream would play the corresponding segment, and biometric data, music, weather, and the gesture itself would be displayed in a popup (see Figure 14(b)). Despite prompting, the notion of visualizing long term data patterns was not explored in detail by the group. All participants agreed to have a large map that show the emotion's location and the runner's path; a click on the landmark of the emotion will create a pop-up window to display biometric data for that emotion, including speed, heartrate and elevation. The pop-up window also has icons for the music and video. A slide-bar under the map was provided in case a user clicks on a video icon, the video related to the emotion will appear bigger and begin to play. Moreover, the graph presents the value of the speed, heartrate and distance for any points of the line, including the emotion location. Participants suggested an optional button (sort by) if users wish to organize their video based on speed, heartrate or climb, as well as link to view the run's whole video.

The Future Technology Workshop helped our participants bypass current technology limitations and focus on their needs regarding improving body fitness, the quality of their runs, and reduce the barrier of performing actions to capture feelings while running so that they can improve their physical and mental health as well as enjoy their runs. Our participants did not prefer to manually capture any data and they decided to have a nano-chip in their brain for capturing brain wave signals to detect user emotion whereas in the visualization they wanted to replicate a 3D model of themselves and integrate their data to create the model. The model will replicate the person's current body structure, condition of muscles, blood flow etc. This shows that people want a technology that will sense their emotion automatically without requiring them performing manual actions on any applications and that will help them to better understand them and improve their future runs. Our work builds on current technologies (e.g. Runkeeper) that are commonly used by recreational runners. Even so, we are motivated to develop a low-attention capture application that requires minimal user interaction for capturing emotional state during a run.

CHAPTER 5 CONTROLLED STUDY DESIGN

The practical goal driving the research in this thesis was to create a low-attention interface for individuals to quickly record their emotional states. Design outputs and feedback from participatory design indicated a need for more control over how an emotion is captured, and the ability to define the emotions that can be captured. Small gesture sets are readily learned, but increasing the number of gestures (to capture other emotions) increases the need for rehearsal and the chance for error, two factors that reduce the attractiveness of an increased gesture set in a lightweight, low-attention interface.

We considered that capturing *how* a gesture is made could allow users to encode qualitative information about an emotion without the need to increase the gesture set. We felt the 5 identified touch gesture attributes (speed, location, pressure, width, and length) could together or individually be used as channels for such expression. This led us to ask two questions. First, will users be consistent (on an individual basis and across users) in how they use touch gesture attributes to express qualities of an emotion? Second, can users recognize emotion qualities in gesture animations?

We developed a smartphone application to capture touch gestures including the 5 touch gesture attributes, convert and save the gestures as animations using SVG in a manner that encodes each of the attributes. We used the capture application interface in a controlled study to explore our questions. The study is described in this chapter.

5.1 Research Questions

In this study, we consider the following research questions:

1) Can people express emotional intensities through gestures?

   - While there are other qualities of an emotion that one might express, we felt that intensity was an aspect shared across a wide range of emotions. Our aim was to understand how people change their way of recording an emotion using touch gesture when expressing it at 3 different intensities: mild, moderate and extreme.

2) Are people able to understand emotional intensities from expressed gestures?

   - We wanted to see if people could identify the intensities of emotions from the animated gestures (made by themselves or others).

5.2 Hypotheses

This led us to hypothesize that:

H1: Consistency: People will be consistent in choosing the same attribute(s) to express intensities for a given emotion

H2: Mapping: People will be able to correctly interpret changes in attribute(s) presented in gesture animations as representing a corresponding change in emotional intensity.

5.3 Participant Recruitment Procedure

We recruited participants (Appendix A) by inviting members of the Dalhousie University community who subscribed for the university daily digest via email (notice.digest@dal.ca). Members of this mailing list constitute a diverse group of faculty, staff and students. No particular experience was required to participate in the study. We did not control for any demographic factors (e.g., gender, handedness) except age and all the participants were 18 years of age or older. We wanted to see trends or common patterns of how participants drew gestures to express emotional intensity. Moreover, to detect consistency (if it exists) in how intensity is expressed, as well as the amount of variance across participants in how specific gestures are made.

5.4 Participants

We recruited 26 individuals through campus mailing lists at Dalhousie University. The participants were 18 to 52 years old (M=26, SD=7.7). Of the 26 participants, six frequently drew gestures on paper notes (smiley faces, hearts, doodles), 16 did so occasionally, and the remaining four did not. All participants had regularly used one or more types of touchscreen device for at least a year. Each participant was compensated $30 for taking part in two sessions (See Appendix F for participant payment receipt).

5.5 Study Methodology Details

5.5.1 Gesture Set

In determining which emotions to use, we started with Ekman's [11] seven universal emotions (Surprise, Happy, Fear, Anger, Sadness, Disgust, and Contempt). We removed disgust and contempt as we felt they may not easily be expressed by all participants at different intensity levels. We then considered a number of emotional states common to the affective experience of recreational runners that were explored in our first study with participatory design approach [4]: bored, tired, mellow, euphoric, and exhilarated. Of these, we chose three (bored, tired, mellow) that we felt might be readily expressed at varying intensities.

We then developed simple gestures for the remaining five universal emotions and the

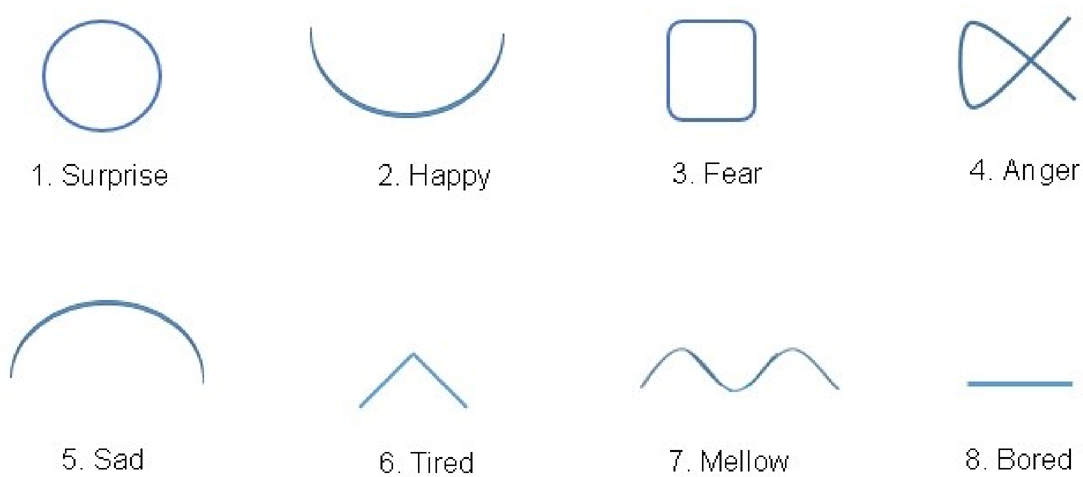
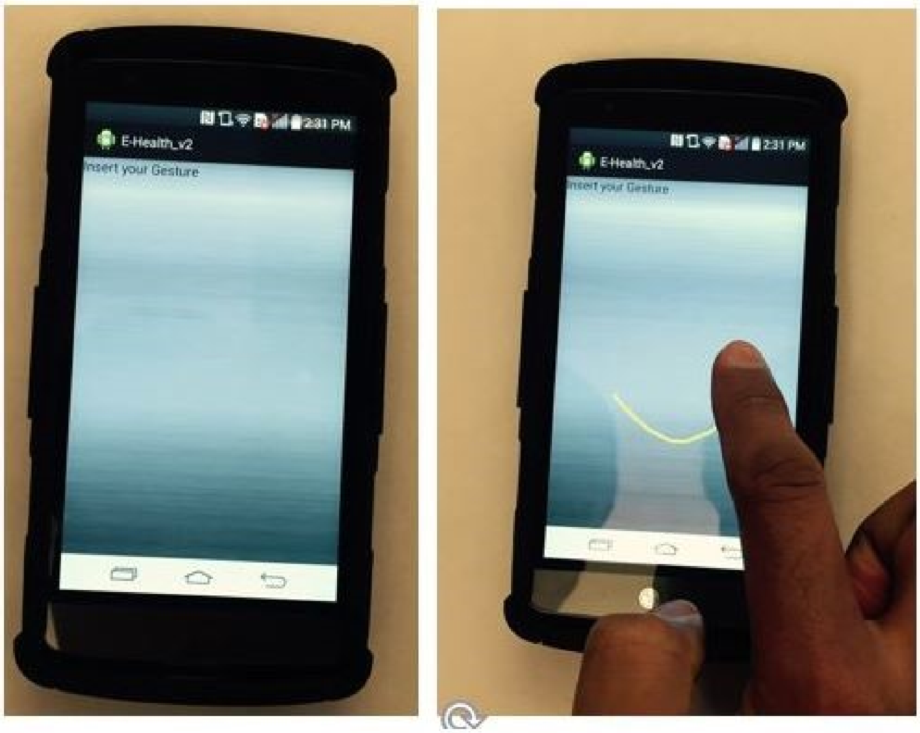


Figure 15 Gestures for our selected eight emotional states

three running related emotional states, as shown in Figure 15. The gestures were inspired from Pirzadeh et al's [40] multi-touch gestures, Lu et.al's [32] gestures to operate mobile user interfaces and Ekman's facial expressions [11]. All gestures required a single touch, were simple, and distinguishable from each other. Again, we were not interested in the suitability of the gestures per se but rather how people modify gestures to express emotional intensity.

5.5.2 Experimental Apparatus



(a) (b)

Figure 16 Our controlled study (a) Touch enabled mobile display to insert a gesture (b) A continuous touch gesture drawn for a 'happy' emotion

The capture application allowed users to draw continuous touch gestures (see Figure 16). The application converted each gesture to an animated colored SVG image that was stored on the device. While these features were developed we simultaneously tested the application with colleagues in the GEM lab. We asked them to draw random gestures to test if the gesture path was displayed properly and verified that the SVG animations functioned correctly.

We also developed two study tools in Java. The first application was used in session 1. It generated a random emotion with an associated intensity and displayed that emotional

Figure 17 Application interface to display each emotion with an associated intensity. The (#) refers to the corresponding gesture number of the emotion written on the participant's reference list)

intensity as an image for all the listed emotions (surprise, happy, afraid, angry, sad, tired, mellow, bored) (see Figure 17).

The second desktop application (see Figure 18) was used in session 2 to recognize the animated gestures.

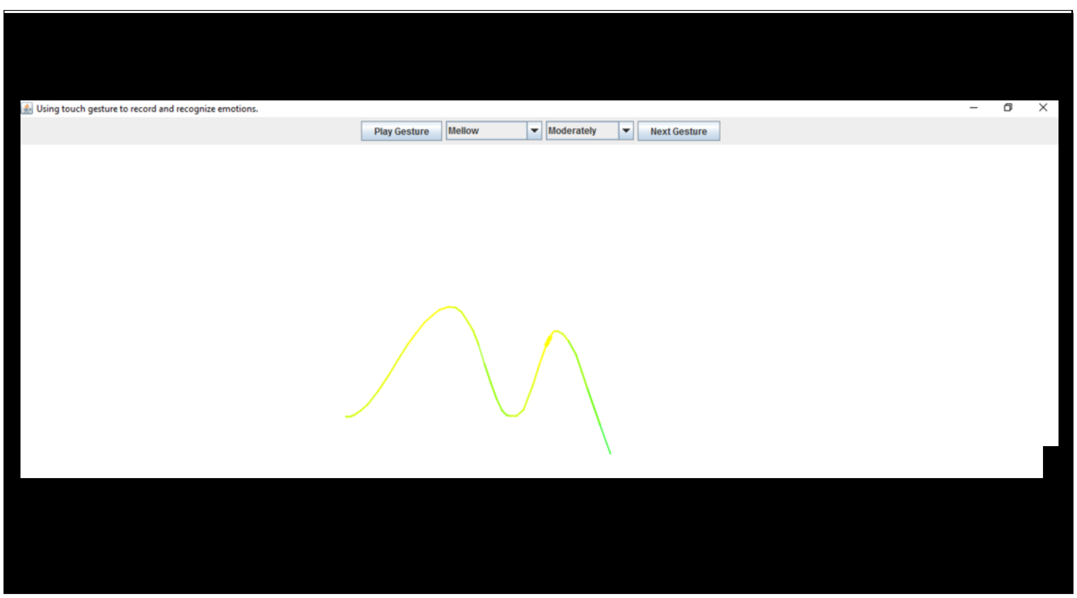


Figure 18 Interface for Session 2. An animated gesture for an emotion is played on the main panel. On top of the gesture there is a replay button, dropdowns allowing the participant to label the gesture according to emotion and emotion intensity, and a button to show the next gesture

Pressure was visualized using a linear mapping of pressure to colour spectrum values from green (low) to red (high), as shown in Figure 19.

Figure 19 Gestures for 'Anger' in three intensities (mild, moderate, extreme) drawn by a participant. Colour indicates pressure (green is low, red is high)

5.5.3 Study Procedure

We conducted a pilot study with three participants from our research lab. Each participant was asked to use the capture application and draw gestures on the screen referring to the list of eight emotional states (see Figure 15) with three intensities (mild, moderate, and extreme). All participants suggested it was easy to draw the gestures and they could identify most of the emotions and intensities from the animated gestures.

For the main study, we met participants in the GEM lab on the fourth floor of the Mona Campbell Building. After meeting the participants, we described the study and answered any questions prior to starting the study, got informed consent (Appendix B2), and participants completed a short background questionnaire (Appendix C).

Afterwards, participants went through a two-part training procedure. First, participants drew each gesture 3 times for a total of 24 times on the handheld. For a better understanding of the functionalities of our application, getting familiarized with five factors (gesture length, pressure, speed, thickness, and position) and the tasks, we asked participants to draw the ‘surprise’ gesture for the following scenarios:

1. Draw the gesture with some pressure

2. Draw the gesture with less pressure

3. Draw the gesture quickly

4. Draw the gesture slowly

5. Draw a big gesture

6. Draw a small gesture

7. Draw the gesture on top right of the screen

8. Draw the gesture on bottom left of the screen

9. Draw the gesture on middle of the screen

10. Draw the gesture with the tip of the finger

11. Draw the gesture with the surface of the finger

Participants were then told that they could use any of the five factors to express emotional intensity during the study. Importantly, we did not provide any guidance as to how to express intensity of emotion. This is because, we wanted to study how expressive different intensity of emotions were and how do they differ from participant to participant. In the experiment, after viewing a named emotion and an intensity (e.g., moderately happy, extremely afraid), participants used the handheld to draw the gesture with the specified intensity. Each gesture had to be drawn in a continuous manner on the mobile screen using a finger of their choice. We associated the eight emotional states (surprise, happiness, fear, anger, sadness, tired, mellow, bored) with three intensities (mild, moderate, extreme; e.g., if the emotion is '*surprise*', then mild intensity referred to: less surprised, moderate intensity referred to: moderately surprised, and extreme intensity referred to: extremely surprised) which resulted in total 8 x 3 = 24 gestures.

After training, each participant was shown 120 emotional states with an associated intensity (mild, moderate, extreme). For each displayed emotional state, individuals had to draw the corresponding gesture on the mobile device.

We followed an ABA design to conduct the gesture capture trials: in the first block ("First 48"), each participant was presented with a sequence of 48 emotional states on a desktop screen with an associated intensity (mild, moderate or extreme). States were presented in random order, and each emotion/intensity pairing appeared twice in the set. In the second block, each emotion was presented once at each intensity level in turn (mild, then moderate, then extreme), to encourage consistency in how intensity was expressed for a given emotion. The third block ("Final 48") repeated the protocol of the first block. After completing all trials, participants were scheduled to return a week later for phase two.

In the second phase, participants were shown 96 animated gestures and asked to identify the corresponding emotion and intensity. There was no time limit, and participants were told they could take a break as needed. Participants were first shown example animations, and the mappings of gestural attribute to animation feature were described (specifically, we ensured they understood that colour mapped to pressure; the other mappings were quite direct). All gesture animations were taken from the third block (the Final 48) in the first phase of the study, as we expected participants to be more consistent in how they expressed intensity in that block. The 96 gesture animations were divided into two blocks of 24 followed by a block of 48. The first block of 24 were animations of their own gestures (all eight emotions at each of the three intensities, presented in random order). The second block of 24 were randomly sampled from the "final 48" sets of all other participants (selecting one of all eight emotions at each of the three intensities). Finally, a block of 48 was presented that was a random ordering consisting of two of each of all eight emotions at each of the three intensities; one from the participant, and one from the pool of other participants. These were taken from the remaining 24 gestures from the participant's Final 48, and 24 randomly sampled from the Final 48 gestures of all other participants (minus the previous 24 sampled).

5.5.4 Data Collection

The data was collected using application logs to store the position of the gesture drawn in the mobile device, the length and thickness of the gesture, the amount of pressure imposed on the device and speed while drawing the gesture. These logged data allowed us to capture how participants interact with the application. These data also allowed us to measure how participants respond to the given emotions to be drawn as a gesture. All logged data was transferred off the device after each participant finished the study and stored on a secure server only accessible by the researchers.

5.5.5 Analysis

After completing each phase of the controlled study with a participant, we organized their data from phase one in a single separate file and from phase two we collected the responses of the emotion and intensity for each displayed gesture in a separate file. Then we cut out the very beginning (the portion where pressure was zero until it increased to a stable value) and very end (the portion where pressure was at a stable value until it decreased to zero) of each touch gesture to remove pressure spikes and velocity shifts common at the endpoints of touch gestures. This was a common situation to consider as the pressure and velocity values were logged in when the touchscreen interface sensed a touch interaction and then the sensor logged almost a stable value while participants were drawing the actual gesture. We calculated the centroid of each gesture (polygon) as a gesture position value, converted velocity vectors to scalar speed values and took the average for each gesture, and normalized the attribute value ranges for pressure, length, width, and speed (to 0-1) to facilitate multidimensional comparison. We considered different ways of analyzing multidimensional factor analysis and identified matrix scatter plots and Principal Component Analysis (PCA) as good means to analyze multivariate dataset. The matrix scatter plots gave a visual sense of the overall captured information and PCA identified correlations within our considered factors (length, pressure, width, speed, and position).

We generated two-dimensional scatter plots across all pairs of factors for each emotion and intensity, split by First 48 and Final 48, to get a visual sense of the contributions of each factor in expressing emotional intensity and their possible interactions. We also applied Principal Component Analysis (PCA) to further explore which factors were correlated and uncorrelated based on our collected dataset. The dataset was organized by participants (1-26), emotions (1-8) and intensities (1-3). After this, we performed a number of targeted analyses (e.g. ANOVA, Post-hoc analysis, Pearson correlation coefficient) to explore interesting trends or correlations.

Recognition accuracy (of participants) was generated as a percentage by calculating the total number of correctly classified emotions and intensities for each participant. This was done based on the decisions made by them in each of the three blocks in phase two of the study. We additionally considered whether intensity classification ranges corresponded with intensity expression ranges. We created the range values for individual participants and compared with the range that they used to interpret an emotional intensity (e.g., if a participant drew all 'mildly surprised' gestures with pressure value ranging from 0.4 – 0.45, we considered the range as: 0.4 – 0.45 for that specific emotional intensity, and then checked what range of pressure values they interpreted as 'mildly surprised' animated gestures in the second phase of the study). We also considered whether specific factors led to better recognition by identifying participants who had a higher accuracy and then assessing whether they were more consistent in using certain factor(s).

CHAPTER 6 STUDY RESULTS

We present the results of our controlled study in this chapter. First, we talk about the findings and discuss how participants used different factors in expressing the three intensity levels. Second, we show the correlation among the five factors and their characteristics from the study. Third, we present the differences in using these factors to express intensities among participants. Finally, we discuss visual understanding and mapping the animated gestures to extract emotions and associated intensities.

6.1 Controlled Study

6.1.1 Mapping intensities with factors

Our scatter plots illustrated a pronounced increase in consistency in the way factors were used to express intensity between the First 48 and Final 48 blocks, as anticipated. Figure

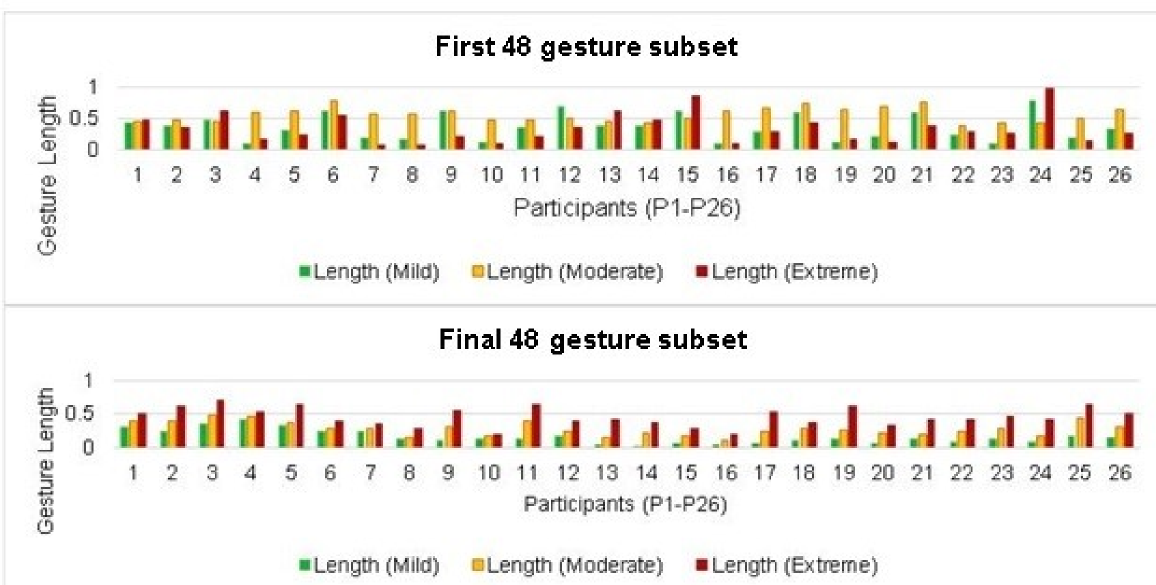


Figure 20 Gestures for our selected eight emotional states

20 illustrates this for surprise. This suggests that practice (and perhaps the structured practice of the middle block) was needed before participants settled into a pattern for expressing emotional intensity on the touchscreen. In the remaining results we consider only the Final 48 block unless explicitly stated otherwise.

It was evident that gesture position did not vary for the majority of participants: gestures

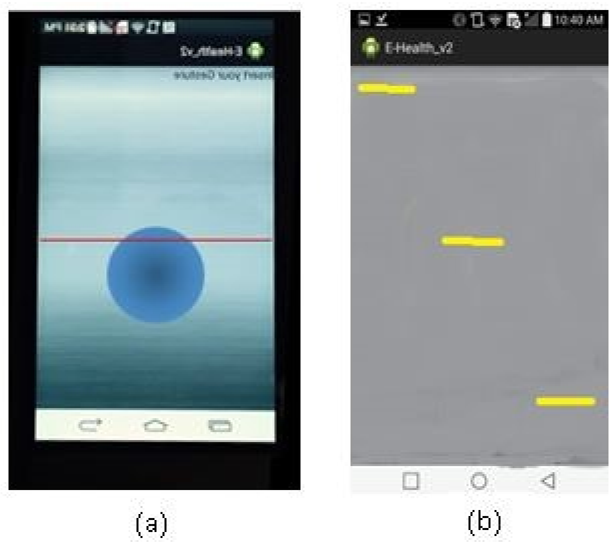


Figure 21 (a) Standard gesture position on an Android smartphone (b) Different gesture positions for ‘Bored’ in 3 intensities by P10

were horizontally centered and vertically toward the bottom half of the screen (see Figure 21(a)) with the exception of 1 participant (P10, see Figure 21(b)). As a result, we omit gesture position in further analysis.

6.1.2 Correlation among factors

Our Principal Components Analysis (PCA) considered the factors of gesture length, pressure, speed, and width. Table 3 shows correlations among these factors. Pressure and gesture width are highly correlated: applying pressure makes the fingertip spread on the

	Length	Pressure	Speed	Width
Length	1.000	-.378	.600	-.317
Pressure	-.378	1.000	-.272	.937
Speed	.600	-.272	1.000	-.231
Width	-.317	.937	-.231	1.000

Table 3. Correlation with Principal Component Analysis

touchscreen. Gesture length and speed also show a positive correlation: moving the finger quickly may cause it to travel farther on the touchscreen. We also note a slight negative correlation between length and pressure: friction and inertia created by increasing pressure may be at play here. Due to the very strong correlation between pressure and gesture width, we consider only pressure in subsequent analysis.

6.1.3 Expression criterion for individual factors

All of our participants used their index finger to draw all the gestures and primarily used a combination of the three factors: gesture length, speed and pressure to express emotional intensities. Here, we discuss the result for each of the five attributes that were suggested to the participants during the study.

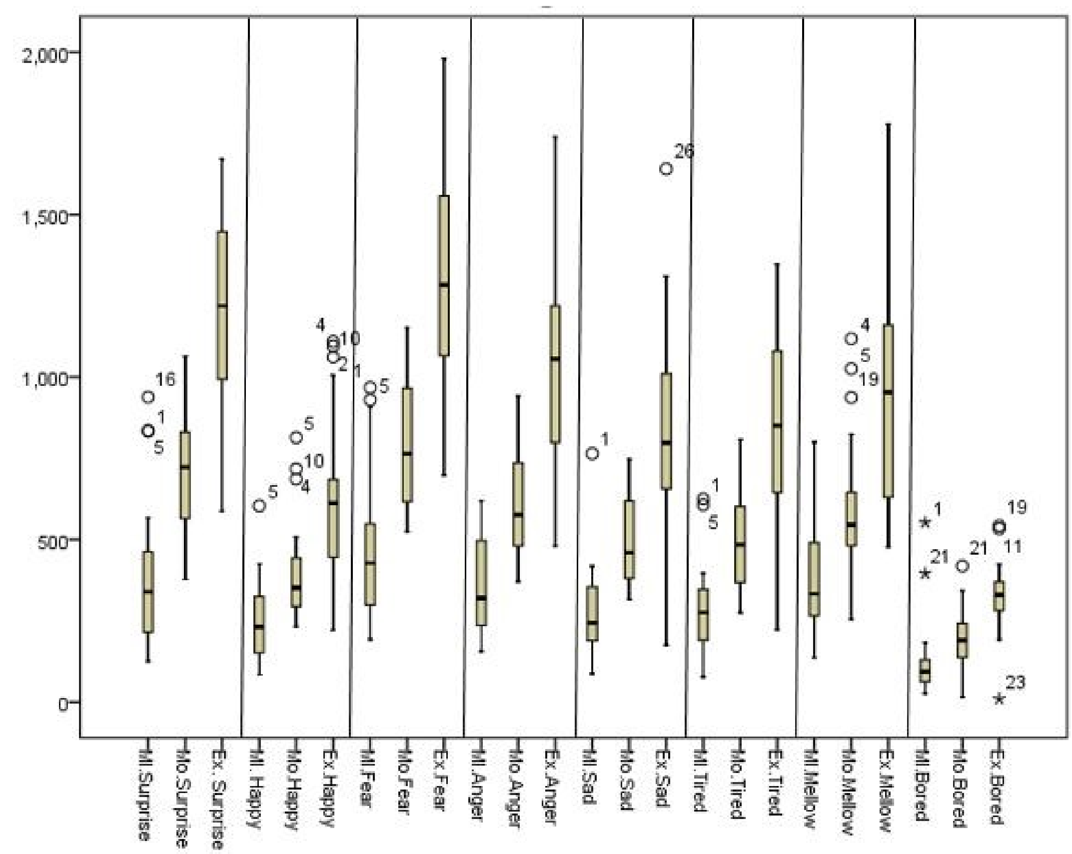


Figure 22 Change in gesture length for eight emotions in three intensities.

6.1.3.1 Gesture Length

We found that for the emotions considered, gesture length increased linearly with increasing intensity (see Figure 22). The rate of difference from mild to moderate and moderate to extreme intensity was investigated using Pearson product-moment correlation coefficient. There was a strong positive correlation between these two variables, $r = 0.634$, $n = 208$, $p < 0.0005$ which suggests the amount of change is linear, but as Figure 22 illustrates, the magnitude of change differed between emotions. Bored, for example, starts as a small gesture and increases in length only slightly as intensity increases, while the increase for surprise is much more pronounced.

6.1.3.2 Gesture Drawing Speed

Drawing speed was also used to express intensity, though we note the correlation between distance and speed in our PCA analysis. For all emotional states with the exception of Mellow, speed increased with intensity (see Figure 23). However, in contrast to gesture length, for Surprise, Happiness, Fear and Anger the rate of speed rises from moderate to extreme (Mild to Moderate increase rate of speed: M=35.7%, Moderate to Extreme increase rate of speed: M=63.9%), whereas for Sad, Tired and Bored, the rate of increase falls off between moderate to extreme (Mild to Moderate increase rate: M=39.2%, Moderate to Extreme increase rate: M=29.2%). Mellow shows an average increase in speed from mild to moderate, but an average decrease in speed from moderate to extreme intensity. It appears that for "lower energy" emotional states (sad, tired, bored, mellow), speed increase rate drops (or speed even lowers) as intensity rises.

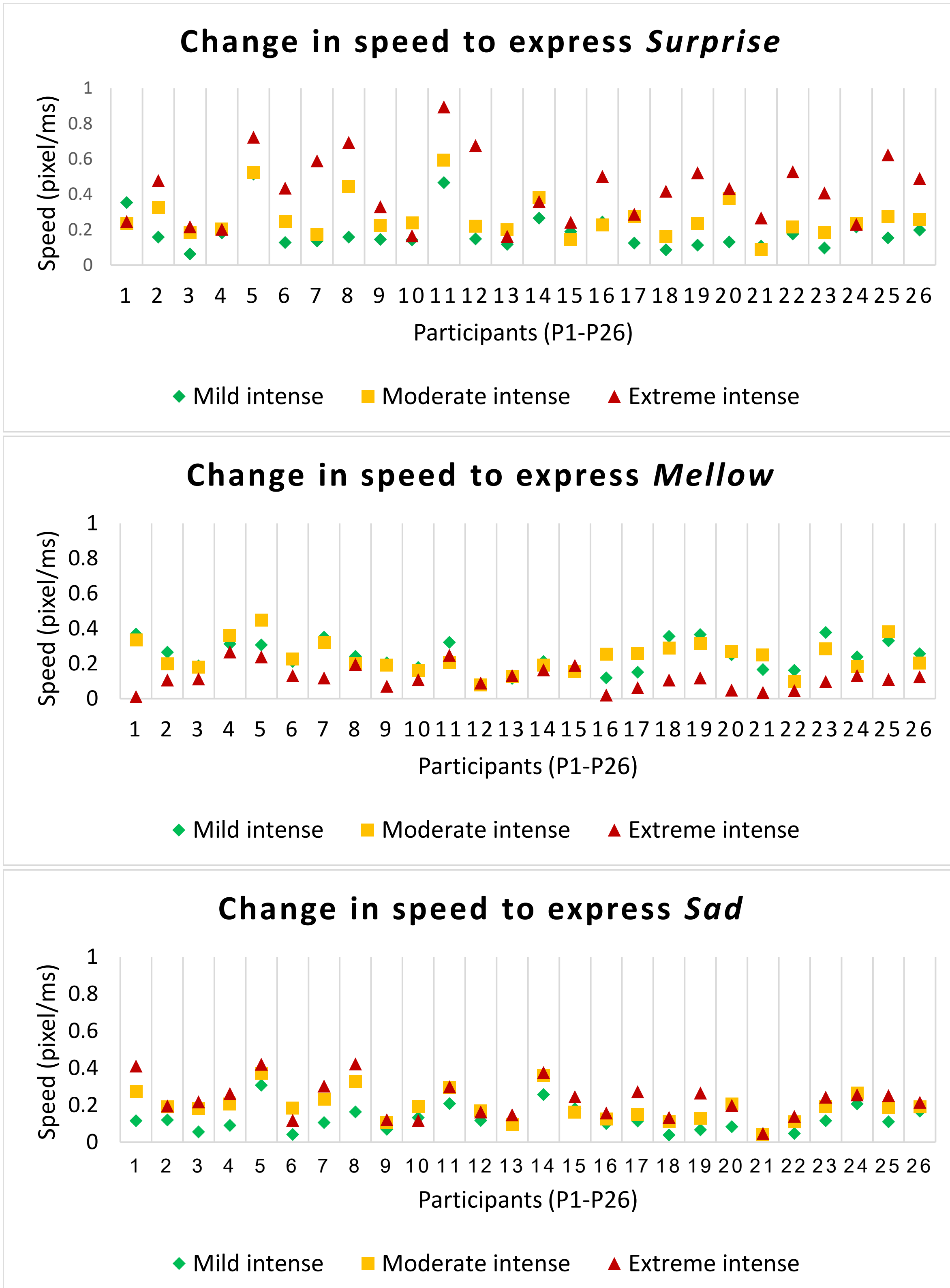


Figure 23 Drawing speed changing patterns within 3 intensities across all participants for 'Surprise', 'Mellow' and 'Sad' gestures

6.1.3.3 On-screen Pressure

Table 4 shows the change in pressure for each emotion. Average pressure across

	On-screen Pressure					
	Mild Intensity		Moderate intensity		Extreme intensity	
Emotions	Mean	SD	Mean	SD	Mean	SD
Surprise	0.57	0.05	0.57	0.04	0.58	0.05
Happy	**0.52**	**0.09**	**0.57**	**0.11**	**0.63**	**0.13**
Fear	0.55	0.04	0.56	0.04	0.58	0.08
Anger	**0.57**	**0.11**	**0.66**	**0.10**	**0.77**	**0.11**
Sad	0.54	0.04	0.55	0.05	0.57	0.11
Tired	0.53	0.10	0.56	0.12	0.57	0.14
Mellow	0.53	0.05	0.53	0.11	0.53	0.07
Bored	0.55	0.08	0.58	0.08	0.59	0.10

Table 4: Pressure means across three intensity levels for our selected emotions

participants increased for Happy and Angry as intensity rose, with anger in particular having the highest average pressure for moderate and extreme intensities by a wide margin. A one-way between subjects ANOVA was conducted to compare the effect of pressure on each emotion. There was significant effect of pressure in three intensity levels: mild intensity [$F (7,200) = 8.38$, $p < 0.05$], moderate intensity [$F (7,200) = 14.19$, $p < 0.05$], and extreme intensity [$F (7,200) = 14.74$, $p < 0.05$]. Post hoc comparisons using the Tukey HSD test indicated that only for Happy (Mild: M=0.52, p<0.05, Moderate: M=0.57, p<0.05, Extreme: M=0.63, p<0.05) and Angry (Mild: M=0.57, p<0.05, Moderate: M=0.66, p<0.05, Extreme: M=0.77, p<0.05), pressure significantly increased in three intensities which was not the case for the remaining emotions.

6.1.3.4 Gesture Width

We applied PCA and considered the factors gesture length, speed, pressure, and width. Our findings show that on-screen pressure from touch is highly correlated (0.937) with the width of the gesture (Table 3).

6.1.3.5 Gesture Position

Our participants did not use position as a factor to express the three intensities. As described before, all the gestures were centered around the lower middle part of the mobile screen, with only one participant using position as a factor for expressing all the displayed emotional intensities (see Figure 21).

6.1.4 Individual Differences in Expression

While these trends were quite consistent across participants, there were individual differences. We identified and classified primary and secondary strategies in terms of how the set of factors were used by participants to express each emotion (see Figure 24). Note that we had two data points per emotion+intensity combination for each participant in the Final 48 set; as a result, we present each strategy according to percentage of all gestures made for that emotion+intensity. The table indicates that for a given emotion, strategies tend to differ in terms of adding or removing a factor in expressing intensity. Divergence occurred only in how speed was used: 12% increased speed for Mellow, opposite to the majority. Similarly, 12%, 15%, and 23% reduced their speed as intensity rose for Happy, Tired, and Fear.

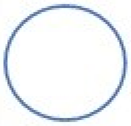
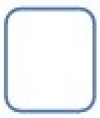
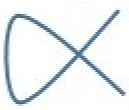
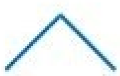
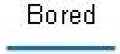
	Primary strategy		Secondary strategy		Other strategy	
Surprise 	Length ↑	42.3%	Length ↑ Speed ↑	38.46%	Length ↑ Pressure ↑ Speed ↑	7.69%
Happy 	Length ↑ Pressure ↑ Speed ↑	50%	Length ↑ Pressure ↑	30.76%	Pressure ↑ Speed ↓	11.53%
Fear 	Length ↑ Speed ↑	57.69%	Length ↑ Speed ↓	23.08%	Length ↑ Pressure ↑ Speed ↑	15.38%
Anger 	Length ↑ Pressure ↑ Speed ↑	61.53%	Length ↑ Pressure ↑	26.92%	Pressure ↑ Speed ↑	7.69%
Sad 	Length ↑ Speed ↑	46.15%	Length ↑	34.61%	Length ↑ Pressure ↓	11.53%
Tired 	Length ↑	42.3%	Length ↑ Speed ↑	30.76%	Length ↑ Speed ↓	15.38%
Mellow 	Length ↑ Speed ↓	57.69%	Pressure ↑ Speed ↓	26.92%	Length ↑ Speed ↑	11.53%
Bored 	Length ↑ Speed ↑	57.69%	Length ↑ Pressure ↑	23.08%	Length ↑ Pressure ↑ Speed ↑	7.69%

Figure 24 Gesture expression strategies across participants for each of the eight emotional states; ↑ means linear increase and ↓ means linear decrease across three intensity levels for the related factor

6.1.5 Recognizing expressed emotions/intensities

97.4% (SD=1.2) of the emotion gestures were correctly identified by all of the participants. However, correctly identifying the intensities of those emotions varied. For one's own gestures, recognition accuracy ranged widely between participants, from 50% to 98%. The recognition accuracy for emotional intensity expressed in the gestures of others also ranged widely, from 44% to 80%. Unsurprisingly there is a statistically significant decrease in accuracy between identifying one's own emotion intensities (M=70.69%, SD=13.4) versus those of others (M=60.15%, SD=9.5), $t(25) = 4.41$, $p < .0005$ (two-tailed).

Table 5 shows the overall recognition accuracy for each of the three intensities and also the number of gestures correctly classified or misclassified by all participants for the three intensities (mild gestures classified as mild or moderate or extreme and so on). Misclassification for two extreme ends (mild as extreme or vice versa) was low, as Table 5 illustrates.

Intensities	**Mild**	**Moderate**	**Extreme**
Overall recognition accuracy	64.07% 18.87 (*SD*)	54.93% 14.46 (*SD*)	71.97% 17.49 (*SD*)

Classification	**Mild**	**Moderate**	**Extreme**
Mild	555	284	27
Moderate	173	476	218
Extreme	16	227	624

Table 5. Overall recognition accuracy and classification distribution of all gestures in three intensities

We also conducted a paired t-test to see if there was a difference in recognizing intensities for one's own gestures in the first block of 24 (all one's own gestures) vs. the third block of 48 (one’s own gestures mixed with the gestures of others). We found no significant difference for accurately interpreting intensities of one’s own gestures presented in isolation (M=68%, SD=13.53) or mixed randomly with other gestures (M=72.7%, SD=13.02), t (25) = -.746, p = .463. We note that there may be a learning effect here, as we did not counterbalance the order of these blocks.

We placed participants into two groups: Group A used the same gesture factors in a consistent way to express emotional intensity, while Group B used gesture factors in a less consistent way. As may be expected, Group A had higher recognition accuracy than Group B overall (Table 6), and this is most pronounced for one’s own gestures.

		Emotional Intensities		
Groups	Category	Mild	Moderate	Extreme
Group A (10)	Own	73.58%	64.33%	81.86%
	Other	65.94%	60.2%	75.14%
Group B (16)	Own	54.73%	53.76%.	65.84%
	Other	57.16%	54.06%	69.83%

Table 6. Mean recognition accuracy of emotional intensities for own vs others gestures based on consistency (Group A: consistent, Group B: less consistent) in using factors.

6.1.6 Influence of visual presentation

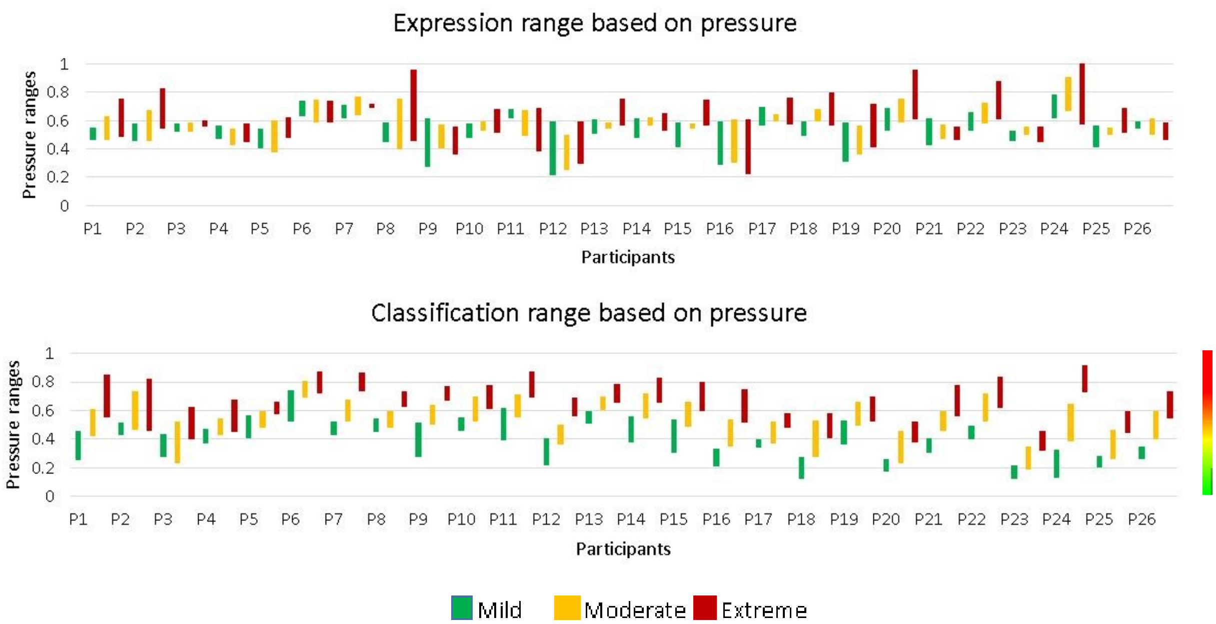


Figure 25 Top: Expression range for pressure to express mild, moderate and extreme intense emotional states for 26 participants. Bottom: Classification range for pressure to classify mild, moderate and extreme intensities and emotional states by the same participants

Figure 25 shows the mapping of pressure to emotional intensity used by all participants when expressing (study phase 1) and recognizing (study phase 2). Each participant used a different range of pressure values to express emotional intensities in phase one (see Figure 25 (Top)). However, participants were more uniform in their mappings of pressure to intensity during recognition in phase 2. As Figure 25 (Bottom) shows, for many participants the recognition mappings correlate with the colour range used by the visualizer: green for slight, yellow for moderate, and red for extreme.

CHAPTER 7 DISCUSSION AND FUTURE WORK

In this chapter, we first discuss the controlled study and how the factors contributed in expressing emotional intensities in a touch interactive application. Afterwards, we talk about consistency in manipulating gestures using different factors and identifying expressed emotional intensities from animated gestures. Furthermore, we discuss about the participatory design study to develop our capture application and visualization interface prototype. Finally, we identify limitations of this work and possible research directions in the future.

7.1 Overview: Controlled Study

Our controlled study was designed to evaluate if individuals are able to express emotional intensities by drawing gestures and if these gestures are understandable and identifiable by them at a later time. In the first session of the controlled study, participants expressed emotional intensities using gestures and in the second session they were asked to identify the corresponding emotion and the intensity from a set of animated gestures. Here, we discuss about our sample gesture choices and relative findings from the controlled study.

7.1.1 Touch gestures for conveying emotions

As we have discussed in section 2.2, Pirzadeh et. al [40] proposed a set of multi-touch gestures to represent facial expressions. Our proposed gestures were inspired from these multi-touch gestures and from the universal emotions from facial expressions suggested by Ekman [11], and our gestures were drawn using a single continuous touch. We were inspired to create continuous and simple haptic gestures for interaction as suggested by

Salminen et al. [44] described in section 2.3 where they suggested this way of interaction can carry emotional information.

However, a goal of our research was to create a low-attention application so that people can easily interact with it and be expressive to record gestures considering Gaver's [15] related dynamics (novel sensors, interaction techniques, and increased engagement) while using the device via touch interaction. We used pressure sensors to understand the articulateness of the emotional intensity. Furthermore, we used touch interaction technique to allow users for demonstrating natural expressions. Furthermore, we used a sample set of distinct gestures to conduct our controlled study as mentioned earlier and we were not interested in the suitability of the gestures but analyze how people will modify gestures to express emotional intensity.

As Park et. al. [39] asked their participants to use their index finger during expressions because they determined the movement is more natural, and stable. All of our participants without prior suggestion used their index finger to draw all the gestures. Therefore, we feel that in this way our participants articulated their emotions more naturally to express all the corresponding gestures.

7.1.2 Contribution of factors in expression

Researches on handwriting analysis as mentioned in section 2.2 suggested that different factors such as size, pressure, line thickness, writing velocity and position are very good indicators to identify specific author's pen on paper handwriting style. Our work focused on the ability of an individual to draw gestures to express emotional intensities and also have the understanding of these gestures' expressiveness and identity. So, we focused on the proposed five factors: gesture length, drawing speed, on-screen pressure, gesture thickness and relative position.

Analyzing our proposed factors using PCA shows a set of positive/negative correlations between gesture factors, making it problematic in treating them as orthogonal channels of expression. Friction, momentum, and physiological factors (finger size, suppleness, motor control) all constrain and influence how the factors are used and how they interrelate. Despite this, our participants were able to use several factors effectively for expressing emotional intensity.

Varying the length of a gesture was a very common way to express emotional intensity across emotions and for all participants, with longer gestures generally meaning more extreme intensity. However, Bored, for example had a small change in magnitude unlike other emotions. One reason might be that bored was identified as an extreme emotional state by our participants. We believe that the visibility of gesture length (as shown by the yellow trace) may have encouraged participants to choose this attribute. Adding immediate visual feedback for pressure, stroke width, and speed may encourage greater variety in expression of emotional intensity.

We note some interesting trends in how speed was used in expressing emotional intensities. Using Thamm et al.'s classification of emotions [50], emotions with either positive (attractiveness) or negative (averseness) valences (in our set, these are Happy, Angry and Afraid) saw a higher increase in speed with increasing intensity than for other emotions. It is also interesting to note that for Mellow, many participants decreased their gesture speed as intensity increased. These results illustrate how the emotion itself influences the way that gesture factors are used to express intensity.

Averill identified the emotions Happy and Angry as inner-feeling states which often lead to complex bodily changes and forms of behavior [2]. From our statistical analysis, we found that all of our participants used pressure as one of the main factors to express intensity for Happy and Angry gestures, while pressure was used by a minority of participants or not at all for the other emotions. It may be that pressure is being mapped to inner-feeling states. In fact, it may be that any intensely felt emotion may be mapped to increased pressure naturally: our participants were not actually experiencing the emotions they were asked to express. As mentioned in section 2.4, Park et al. [39] identified that for positive emotions weak touches are delivered and for negative emotions hard, fast, and continuous touches are delivered. However, aside from positive/negative emotions, our findings suggest that the nature of touch also depends on the intensity for expressing an emotion.

Our findings show that while expressing intensities for different emotions our participants used separate combinations from the three factors mentioned above. Section 2.3 talks about this feature where Flagg et al. [13] suggested that speed, length, pressure level, contact area and position can be translated into a unique sense of emotion. However, this may not always be the case based on user convenience to express touch interaction in smaller devices i.e., smartphones or smartwatches. Furthermore, using position to draw intensities may be cumbersome when a person is mobile or in a run. We feel drawing speed, gesture length and screen-pressure can be used as sample factors for consideration in understanding intense expression that can be applied to different interactive devices regardless of their size.

7.1.3 Consistency in choosing and using gesture factors

We hypothesized that people will be consistent in choosing attribute(s) to express intensity for a given emotion (H1) and they will map the attributes to intensity (H2). Not all of our participants exhibited this consistency, although all participants were more consistent after a structured sequence of low-medium-high gestures for each emotion. Participants who were more consistent in this way were better able to recognize their own emotional intensities, and those of others who used the same factors in a similar way.

As described in section 2.4, Liu et al asked their participants to create haptic gestures in three intensity levels for the same emotion and their focus was to identify ways to communicate emotions between remote individuals. Our study was more focused on understanding how an individual can express different emotions in three intensity levels and can they extract these gestures' detailed information from animation. Based on our findings we see that individuals were able to easily draw gestures and the participants who were consistent in using a fixed set of factors were able to better recognize their own gestures and similar gestures made by others.

7.1.4 Identifying emotional intensities

In general, participants were better able to interpret and correctly classify emotional intensity at the extreme ends of the ranges. Recognition accuracy for "moderate" intensity gestures was generally lower than for "low" and "extreme". Participants rarely classified an emotion as low when it was extreme and vice versa, suggesting that a lot of misclassification was due to variation in how emotional intensity was mapped to gesture attribute ranges, rather than to complete misunderstanding. In our study, we used three classifications (low, moderate, and extreme): future work should consider using continuous ranges to better understand interpretation accuracy.

Visual presentation was an important factor influencing the interpretation of gesture intensity. An animation offers potential benefits for recalling affective experience. The mapping of pressure to colour led our participants to classify emotional intensity by colour changes, even though the actual pressure ranges used by participants to express intensity varied, and were sometimes inconsistent with the colour mapping. Adjusting the colour mapping with individual variation in pressure range could increase recognition accuracy for this attribute. We also found that while speed was used to express emotional intensity for a number of emotions, it was not evidently used as a factor when interpreting emotional intensity. This is likely due to the difficulty in noticing slight variations in speed from one gesture to another. Amplifying speed differences during playback may more effectively communicate how this factor is used.

7.2 Implications of study and system design

As our results suggest that people were not able to understand speed differences in most cases and mapped discrete colors (green, yellow, and red) to three intensities (mild, moderate, and extreme) whereas it was not the actual case during drawing as they could not see color of the gesture. Some of these features may have impacted peoples' abilities to make certain choices which made it difficult to interpret.

We found that pressure and thickness were highly correlated and in general people may not use gesture thickness as a factor; we expect that using a stylus could lead to differentiation between pressure and thickness. Similarly, with a larger screen area or for mid-air gestures, gesture position could become a more relevant factor for expressing intensity.

Overall, our study was designed and implemented in a controlled way, where participants had to practice emotion conveyance. This was to make sure that our participants were able to express the pre-defined set of emotions and related intensities. Subconscious emotion measurement was not assessed in our study, as individuals' reactions to events may vary and emotional intensity is heavily dependant on the participants' personality.

7.3 Overview: Participatory design study

We have proposed JogChalker to capture emotional state through touch gestures and visualize these gestures as animations. This was experimented by co-designing our capture application and visualization interface through a participatory design study with feedbacks from participants who were recreational runners.

7.3.1 Participatory Design Outcomes

A goal of our PD sessions was to identify how to integrate gesture-based capture and subsequent visualization of emotional state into an existing app for personal analytics (Runkeeper). This exercise allowed us to define desirable features and interface designs for JogChalker. Inspired by prior work [29] [49], the iterative participatory design approach helped us to learn about specific user requirements through co-designing both individually and in groups.

Our participants were interested to know more about recorded emotions than just the emotion itself, including how emotions change over time, and how they are related to the run - "*I am more concerned about how long it took me to become emotionally happy or tired. It will also help me to find my fitness level, and how the cardio is improving from one run to the next one*" (P2). "*The purpose of the application is to record the emotion and improve the selection of routes by considering the emotions from previous runs*," said P4.

Despite some difficulties, our participants were satisfied with gesture as a means of recording affective experience when running, although they all felt that options for audio and custom gestures should be available. One of our participants (P2) suggested that audio notes would be a better addition to the application, saying: "*Audio will allow me to record notes, things that I suddenly remembered and may forget but touch will not allow me that. Running is supposed to make you relax unless there are a lot of stuffs bothering or bugging you in your mind*". Similarly, P3 suggested to use voice commands to change songs: "*We will be able to make our own voice commands: skip 3; it will skip the next 3 songs.*" On another note, P1 wanted an application which will allow users to create their own gestures before each run: "*I would like to have options to choose before I start my run. A small icon at the top of the application screen to click and create my custom gestures*" (P1). It is important to note that our participants did not use audio annotations during their runs, which introduces other issues (background noise, feeling awkward, breathlessness).

Our PD approach may have generated limited novelty and variety in the visualization interface; participants were primed by the initial prototype and Runkeeper's visualization.

Showing the sketches of other users did encourage participants to think about their decisions, however the designs were very similar to begin with.

Based on our PD findings, an actual system should consider the aspects of keeping both the functionalities of voice and gesture to capture affective experience. As we believe, each of this functionality can be activated/deactivated based on the environment the individuals are in. The controlled study findings may not be applied directly to the running context to capture emotional intensities for recreational runners. Runners may find it hard to use factors i.e., pressure, position, or width suitable and draw gestures while running.

A final system might also allow users to create their own gestures based on their experience and convenience, however this would limit the ability to share annotations and recognize the annotations of others. It may also impact the ability for an individual or system to interpret qualitative attributes (like intensity) in the performed gestures. While no participant suggested encoding additional data in how the gesture is made, we were motivated to explore this as a potential middle ground between standardization and flexibility.

7.4 Limitations

Though the methodology allowed us to explore our research questions and generated useful results, there are several limitations of the work presented in this thesis.

First, the controlled study environment did not provide a suitable atmosphere to make our participants actually feel the emotional states they were asked to record. It is unclear whether participants would record a gesture in the same way if they actually felt extremely angry or extremely sad (indeed, they may not record their emotion at all in such circumstances). Second, we could have used the 'gesture heat maps' suggested by Vatavu et. al [52] to present the variation of a particular emotion expressed at different intensities. The heat maps provide a visualization to identify gestures' articulation differences, which may have improved classification of emotional intensity in some cases. Thirdly, our JogChalker application did not support multi-touch gestures, eliminating another possible channel of expression.

7.5 Future Work

Our initial Participatory Design methodology did not allow us to explore more nuanced aspects of gestural affect capture and visualization, including whether animating gestures supports inference and recall of affective experience, and whether and how long-term use of the interface supports discovery of running patterns leading to enjoyment. Future work could explore both questions.

Based on the limitations of our controlled study, we may find more interesting behavior and able to better understand users' gesture drawing patterns by comparing conscious and subconscious gestures made by people as scribbles/drawings to express a list of emotions. As Ekman [10] has stated, micro-expressions lead to the emergence of universal emotions on the face. It may be that 'micro-intensities' expressed as slight variations in gesture behaviour can be studied for deeper insight into the emotional expressivity of gesture.

Finally, gestural annotation of emotional intensities could be useful in a range of other contexts than recreational running. In addition, the encoding of emotional intensity in a gesture does not require that the gesture itself represent an emotion: our work could be extended to other gestures and touch-based annotation, for example expressive text messaging and interpretation of gestural emphasis in digital art. Besides, a hybrid approach can also be implemented where both gestures and facial expressions can be captured to understand the affective experience of recreational runners.

CHAPTER 8 CONCLUSION

Our research focuses on the affective aspects of touchscreen interactions, and how people consciously use elements of touchscreen gesture articulation (e.g., length, speed, pressure) to convey intensity for a given emotion. It also analyzes how well people are able to recognize emotional intensity when seeing a gesture played back to them as it was made in the form of an animation. To achieve this, we worked on the development of a gesture capture application that allowed users to draw continuous touch gestures on a pressure-sensitive Android device. Besides, we collected the whole gesture path, finger-pressure on the device while drawing the gesture, drawing speed, gesture position, gesture width and created animated images using SVG animation so that the users can easily understand their emotional intensities by looking at those animated gestures.

Furthermore, we recruited 4 recreational runners and conducted a 4-week participatory design study to design a fully functional gesture capture application and a visualization interface design for better understanding prior running data and improve the quality of future runs. Our PD study allowed us to understand what runners need to make their runs more enjoyable. Our participants liked the automatic gesture capture functionality. They wanted to define their own gestures, and all wanted to be able to record voice annotations, instead of or in addition to gestures. Integration with Runkeeper was refined toward a simple interface to enter recording modes, and a screen for reviewing and deleting annotations on the mobile. The group also suggested that recording an emotion could immediately trigger a change in music playlist.

For further evaluation, we conducted a controlled study to explore the expression and interpretation of emotional intensity through gestures. Each gesture was stored in real time while capturing speed, on-screen pressure, length, on-screen position, and thickness. We found that participants used primarily gesture length, pressure and speed to express emotional intensity for a set of gestures representing different emotions. We also feel these factors can be used as an initial set to consider for designing interactive touchscreen interfaces on smartphones. The specific factors used varied with emotion, with pressure used for Happy and Angry most prominently, and speed used for in a manner opposite that for other emotions. When gestures were played back as animations, gesture length and pressure were used to interpret emotional intensities, but not speed. Participants who used gesture factors in a consistent way to express emotional intensity were in turn better able to recognize intensity when gestures were played back.

The PD work helped us to better understand the application requirements and the controlled study generated ways of users' expression for different emotional states. We believe, although gesture position was not used as a contributing factor in expressing emotional intensities in our study, with a bigger screen space (i.e., stylus) it may be a more relevant factor.

In conclusion, we believe this thesis work has paved the way for a new research area to build intelligent emotion-aware touchscreen interfaces and systems. This will be useful for other researchers and practitioners in this area to have a better understanding of creating novel gestures and will be helpful for developers to create user friendly interactive interfaces i.e., expressive text messaging applications, gestural emphasis in digital art. Besides, application design considerations can be evaluated by potential users (for example, if a pattern recognizer identifies a combination of factor values that strongly connotes an intensity, visualization could emphasize this, rather than simply display raw changes in factor values).

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Appendix A – Recruitment Notice

We are recruiting participants to take part in a research study examining how animated touch gestures can be used for evaluating emotion. No specific expertise is required. We will not control for any demographic factors (e.g., gender, handedness) except age and all the participants will be 18 years of age or older.

The study will consist of two sessions and be conducted in the Graphics and Experiential Media (GEM) Lab, on the 4th floor of Mona Campbell building, Dalhousie University, and each session will take about one hour (two hours in total). You will first meet with a researcher to go over the study details, give consent to do the study and fill in a background questionnaire. You will then complete a set of tasks which involves drawing gestures representing different emotions on a mobile device. You will be asked to attend a second session within 5 to 8 days after the first session, where you will be shown a set of animated gestures (made during the first session) and you will be asked to identify the emotion after viewing the gesture. Compensation is $15 cash for each session (total $30 cash for two sessions paid after finishing the second session) in the study.

If you are interested in participating, please contact Nabil Bin Hannan (nabil@dal.ca).

Appendix B1 – Informed Consent (Participatory Design)

Participatory design of an application for capturing affective experience during leisure runs

Principal Investigators: Nabil Bin Hannan, Faculty of Computer Science
Dr. Derek Reilly, Faculty of Computer Science
Co Investigators: Khalid W. Tearo, Faculty of Computer Science
Karan Sharma, Faculty of Computer Science
Felwah Alqahtani, Faculty of Computer Science

Contact Person: Nabil Bin Hannan, Faculty of Computer Science, nabil@dal.ca

We invite you to take part in a research study being conducted by Nabil Bin Hannan at Dalhousie University. Your participation in this study is voluntary and you may withdraw from the study at any time. Your academic (or employment) performance evaluation will not be affected by whether or not you participate. To participate in this study, you are supposed to regularly run distances of 5k or greater and have used fitness trackers and/or mp3 players while running. The study is described below. This description tells you about the risks, inconvenience, or discomfort which you might experience. Participating in the study might not benefit you, but we might learn things that will benefit others. You should discuss any questions you have about this study with Nabil Bin Hannan.

The purpose of the study is to improve the design prototype of our application through iterations to evaluate easier and efficient interaction by capturing and recalling the affective experience of leisure runs. You will be asked to participate in a study where you will go for a run on a specific route and perform a set of tasks. Tasks will involve drawing gestures on the application interface based on the emotional feelings of the participant. You will use the capture application to actively capture affective experience using gesture on a smartwatch or smartphone (you may try both) during at least 1 run per week over a span of 4-6 weeks. You will have two meetings in this study once per week and these meetings will be at the same time. First meeting will be with the lead investigator for a design session and the second meeting will be with co-investigator who will be responsible for visualization interface part. The first meeting may take about one hour and the second meeting may take about half an hour – this is not a requirement for participation however, and you may only run once with the application, or several times within a shorter period than the ideal 4-6 weeks' span.

At the beginning of the study, you will meet with an investigator (at the Mona Campbell building). You will be asked to give consent to do the study. You will be given a general description of the type of tasks we want you to do with the mobile application during the study. At the end of the study, you will answer a few questions as part of design iteration feedback that will ask you to reflect on your ideas to improve the application design prototype.

A low risk is associated with the study in that your attention may be divided when you are using the capture application while running. We will attach the mobile device on your arm so that the device is unobtrusive, and the application is designed to allow you to draw gestures without looking at the screen. If you feel uncomfortable you can stop, draw your gesture, and continue your run.

All personal and identifying data will be kept confidential. The informed consent form and all research data will be kept in a secure location under confidentiality in accordance with Dalhousie University policy for 5 years post publication.

In the event that you have any difficulties with, or wish to voice concern about, any aspect of your participation in this study, you may contact Catherine Connors, Director, Office of Research Ethics Administration at Dalhousie University's Office of Human Research Ethics for assistance: phone: (902) 494-1462, email: Catherine.connors@dal.ca.

"*I have read the explanation about this study. I have been given the opportunity to discuss it and my questions have been answered to my satisfaction. I hereby consent to take part in the study. However, I understand that my participation is voluntary and that I am free to withdraw from the study at any time.*"

Participant

Name: ______________________________

Signature: ___________________________

***Date:* ______________________________**

Researcher

Name: ______________________________

Signature: ___________________________

***Date:* ______________________________**

"*I agree that participation in the experiments will be video recorded for the purpose of analysis. I understand that this is a condition of participation in the study, and I understand that this video record may be used in publication or presentation of results, after being anonymized by blurring faces.*"

Participant

Name: ______________________________

Signature: ___________________________

***Date:* ______________________________**

Researcher

Name: ______________________________

Signature: ___________________________

***Date:* ______________________________**

Please select **one** of the options below:

☐ "*I agree to let you directly quote any comments or statements made in any written reports without viewing the quotes prior to their use and I understand that the anonymity of textual data will be preserved by using pseudonyms.*"

Participant Researcher

Name: ________________________________ Name: ____________________________

Signature: ___________________________ Signature: ________________________

Date: ________________________________ ***Date:*** ______________________________

Or

☐ *"I want to read direct quotes prior to their use in reports and I understand that the anonymity of textual data will be preserved by using pseudonyms."*

[if this option is chosen, please include a contact email address: _____________________________]

Participant Researcher

Name: ________________________________ Name: __________________________

Signature: ______________________________ Signature: ________________________

Date: _________________________________ ***Date:*** ____________________________

If you are interested in seeing the results of this study, please check below and provide your email address. We will contact you with publication details that describe the results.

☐ *"I would like to be notified by email when the results are available via a publication."*

[if this option is chosen, please include a contact email address: _____________________________]

Appendix B2 – Informed Consent (Controlled Study)

Using touch gestures to record and recognize emotions

Principal Investigators: Nabil Bin Hannan, Faculty of Computer Science
Dr. Derek Reilly, Faculty of Computer Science
Co Investigators: Khalid W. Tearo, Faculty of Computer Science
Karan Sharma, Faculty of Computer Science

Contact Person: Nabil Bin Hannan, Faculty of Computer Science, nabil@dal.ca

We invite you to take part in a research study being conducted by Nabil Bin Hannan at Dalhousie University. Your participation in this study is voluntary and you may withdraw from the study at any time. Your academic (or employment) performance evaluation will not be affected by whether or not you participate. No particular experience is required by participants to participate in the study. The study is described below. This description tells you about the risks, inconvenience, or discomfort which you might experience. Participating in the study might not benefit you, but we might learn things that will benefit others. You should discuss any questions you have about this study with Nabil Bin Hannan.

The purpose of the study is to help us to assess extracting the information about different types of emotions and their consistent behavior from a finger-based gesture. You will be asked to participate in a study in two sessions each approximately for 1 hour (2 hours in total) where you will perform a set of tasks. Tasks will involve drawing gestures based on the given emotional state (first session) and identify emotions seeing the corresponding animated gestures (second session, within 5 to 8 days after the first session).

You will be compensated with $30 cash (at the end of the second session) for participating in the study; you can withdraw from the study at any time without consequence. A researcher is always present during the study to answer any questions you may have or address any problems that you may experience with the tasks.

At the beginning of the study, you will meet with an investigator (at the Mona Campbell building). You will be asked to give consent to do the study and to fill in a background questionnaire detailing your experience on using touch interactive devices. You will be given a general description of the type of tasks we want you to do with the mobile application during the study. The first session will end after you finish your given set of tasks. In the second session, you will be asked to perform another set of tasks.

During the controlled study, you will be accompanied by an experimental facilitator at all times. The interaction area will be clear of obstructions, and there are no risks associated with using the tracking hardware used. A very low risk is associated with the study that you might experience some fatigue. To reduce fatigue, you will take a 30 second break after the training session, and after each set of 30 gestures during the experiment. If you do not feel comfortable, you can withdraw from the study at any time. As well, to ensure anonymity of all participants, all data collected (including questionnaire data) will be treated anonymously by using participant identification number.

All personal and identifying data will be kept confidential. The informed consent form and all research data will be kept in a secure location under confidentiality in accordance with Dalhousie University policy for 5 years post publication.

In the event that you have any difficulties with, or wish to voice concern about, any aspect of your participation in this study, you may contact Catherine Connors, Director, Office of Research Ethics Administration at Dalhousie University's Office of Human Research Ethics for assistance: phone: (902) 494-1462, email: Catherine.connors@dal.ca.

> "*I have read the explanation about this study. I have been given the opportunity to discuss it and my questions have been answered to my satisfaction. I hereby consent to take part in the study. However, I understand that my participation is voluntary and that I am free to withdraw from the study at any time.*"

Participant | Researcher

Name: ________________________________ Name: ________________________

Signature: _____________________________ Signature: _____________________

Date: ________________________________ ***Date:*** ________________________

☐ *"I understand that the anonymity of textual data will be preserved by using pseudonyms."*

Participant | Researcher

Name: __________________________ Name: __________________________

Signature: __________________________ Signature: ______________________

Date: ________________________________ ***Date:*** ____________________________

If you are interested in seeing the results of this study, please check below and provide your email address. We will contact you with publication details that describe the results.

☐ *"I would like to be notified by email when the results are available via a publication."*

[if this option is chosen, please include a contact email address: ______________________________]

Appendix C - Background Questionnaire

PART I - PLEASE FILL IN THE FOLLOWING INFORMATION:

1. Age: ________

2. Gender: ☐ Male ☐ Female

3. *If attending university*

   Faculty/department: ________________________________

   Otherwise (not attending university)

   Occupation: ________________________________

4. Do you have any experience with touch gestural interaction technologies?

   ☐ Playing games with finger touch on a mobile device

   ☐ Drawing emoticons in any Watch interface

   ☐ Other(s) ____________________________

5. If yes, how much experience do you have with this gestural interaction technology?

   ☐ None ☐ Less than one year ☐ More than 1 year

Appendix D – Study Design (Participatory Design)

Feedback Questionnaire

1) Were you able to draw gestures while you were running or did you stop every time while you wanted to draw a gesture? If not, what were you uncomfortable with?

Design iteration session 1

1) Do you like the way how gestures are currently made in our application?

   If Yes – What do you think works well?

   If No – Why? What can be included to solve this issue?

2) Can you think of another approach (other than drawing gestures) which can be used in our application to express emotions with low attention during running? Can you sketch how the interface will look like?

3) Would you like your gestures to be recognized while you are running?

   If Yes – Why?

4) How would the interface look like that would allow you to customize gestures? Can you sketch it here step by step? (From starting the application until you close it.)

5) Do you have any other comments or suggestions?

Design iteration 2

In this session, we will show you 'Runkeeper' which is a well-known application for runners. And we will go through step by step to make you familiarize with it.

Ok, this is the Runkeeper application. If you start the application you will see it will start searching for your location.

1) Now, imagine you want to go for a run, what will you select? **2)** Ok, how will you want to select your music? (Is this helpful to interact?) **3)** Now, think you have good GPS and you want to start your run. **4)** You go out for your run for some time and reach your destination. Now what will you do in the application?

So, while you are running, what type of the things will you explicitly like to do/ you think you could enjoy your run more; but cannot do it currently?

Ok, now let's focus on our current gesture application. How can we integrate this part in the Runkeeper application? Here is the screen –

Do you want to select that you want to record your emotion while running?

Where do you want to put that? (Give them time to think)

- Then give them a list of widgets and ask them where can we put it **(Why do you want to put that widget here?)**
- Ok, **what happens when you press this** / Ok, **what happens now?** (Ok, that doesn't make any sense, you have to change that)

Here is the Runkeeper Window- Here is our current gesture application Window-

- Let's design a window that will allow you to design gestures
  (Why do you want to put that widget here?)
- If participant says, Ok, let's put the gesture here. (As you can see, there are a number of active objects on the screen e.g. buttons and so on. So, if you are making a gesture you may easily press stop. **How do you want to deal with this issue?) (**Let them think)
  <u>Help:</u> 1) You might need a special gesture. 2) Or press a physical button in order to get out of gesture mode
  Why did you put it here? What are the benefits/disadvantages of that?
- Ok, now to activate the whole screen – What do we need to do? Why?
  <u>Help:</u> 1) You might hold/ press to activate
- How do you want to add your own custom gestures?

Before finishing today's session, I would like you to come up with all the possible methods you can think of to record your emotion while running? (watch, shoulder, arm, hand movement)

Design iteration 3

We have developed 4 paper prototypes based on the outcomes of the last design session. In today's session, you will use these prototypes to inspire you as a group to design a final, more refined prototype.

Start by reviewing each prototype, and discuss what you like and dislike about them. Disagreements are good at this stage!

Next, list the **features that you feel must be in a final version**, followed by **features** you feel **are "nice to have" but not absolutely necessary**. Consider the tradeoffs between **functionality and simplicity**.

As a group, **sketch out the basic interface using pen and paper until you are happy with the overall layout and flow.** Then use the provided paper prototyping materials to create a mockup.

Now that you have the mockup, discuss whether the following scenarios are adequately supported by walking through interaction with the mockup. You may decide as a group that **one or more of these scenarios is unnecessary to support** (state this if so). Refine the mockup as necessary as you consider each scenario:

1. running on a rainy day
2. running on a cold day with your gloves on
3. running with a group of people
4. running in a race
5. running on a wooded trail
6. running in a busy downtown area
7. running in a new town
8. leisure cycling
9. going for a walk

****** Is it logical/easier if you press go running and select a mode (touch gesture/ audio)?**

Appendix E – Study Design (Controlled Study)

Each gesture has to be drawn in a single continuous touch

5 FACTORS that you can use 1. amount of **pressure** on the screen 2. drawing gesture-**length/size** 3. drawing **speed** 4. drawing gesture-**width** 5. gesture **position** on the screen	**Word meanings:** **Mellow** – Relaxed and satisfied **Word meanings:**

Participant ID #:
Date:

Hi, I'm (researcher's name) and I'm going to train you with our mobile application in 2 phases to draw touch gestures of the aforementioned 8 emotions. In the first phase of the training, you will be drawing each emotion 3 times (for a total of 24 training gestures). In the second phase of the training you will be asked to draw 10 more gestures for 1 emotion using the 5 factors as mentioned earlier.

After you draw a gesture, wait for a message on the mobile screen to pop up saying "save success", that means the gesture is saved. Then you can draw the next gesture and continue similarly.

Training Phase **Starting Time: ______________**

Surprise	***Happy***	***Fear***	***Anger***
Sad	**Tired**	**Mellow**	**Bored**

Now, I would like you to draw the surprise gesture for the following scenarios that I will be telling you -

1. With some pressure2. With less pressure 3. Draw quickly

4. Draw slowly 5. Draw a big gesture 6. Draw a small gesture

7. Draw it on top right of the screen 8. Draw it on bottom left of the screen

9. Draw it on middle of the screen 9. Draw with the tip of your finger

10. Draw with the surface of your finger

Now, for the main session I will *restart* the application and you will draw the gestures accordingly for the emotions displayed on the screen. You have to consider the intensity of emotions while you will be drawing the gestures on the touch screen. Also, try to feel that emotion while you are drawing the gesture. You can speak aloud to express your intensified emotion ex: I am extremely happy!

Appendix F – Participant Payment Receipt

My signature below confirms that I received a sum of $30 (CDN) cash from Nabil Bin Hannan as an honorarium payment for participating in the “Using touch gestures for recording and recognizing emotions” research project.

I understand this honorarium is taxable income and it is my responsibility to claim it on my income tax as Dalhousie University will not be issuing a T4A for this payment.

Name (please print): ________________________________

Signature: ________________________________

Date: ________________________________

Appendix G - Social Sciences & Humanities Research Ethics Board Letter of Approval

Social Sciences & Humanities Research Ethics Board
Letter of Approval

August 14, 2015

Mr Nabil Bin Hannan
Computer Science\Computer Science

Dear Nabil Bin,

REB #: 2015-3621
Project Title: Using Touch Gestures to Record and Recognize Emotions

Effective Date: August 14, 2015
Expiry Date: August 14, 2016

The Social Sciences & Humanities Research Ethics Board has reviewed your application for research involving humans and found the proposed research to be in accordance with the Tri-Council Policy Statement on *Ethical Conduct for Research Involving Humans.* This approval will be in effect for 12 months as indicated above. This approval is subject to the conditions listed below which constitute your on-going responsibilities with respect to the ethical conduct of this research.

Sincerely,

[redacted]

Dr. Karen Beazley, Chair