Title	Ring U : ring-shaped wearable device for interpersonal communication using color lighting and tactile expressions
Sub Title	
Author	Pradana, Gilang A.(Inakage, Masahiko) 稲蔭, 正彦
Publisher	慶應義塾大学大学院メディアデザイン研究科
Publication year	2013
Jtitle	
JaLC DOI	
Abstract	
Notes	修士学位論文. 2013年度メディアデザイン学 第326号
Genre	Thesis or Dissertation
URL	https://koara.lib.keio.ac.jp/xoonips/modules/xoonips/detail.php?koara_id=KO40001001-00002013-0326

Master's Thesis

Academic Year 2013

Ring U: Ring-Shaped Wearable Device for Interpersonal Communication Using Color Lighting and Tactile Expressions

Graduate School of Media Design,
Keio University

Gilang A. Pradana

A Master's Thesis
submitted to Graduate School of Media Design, Keio University
in partial fulfillment of the requirements for the degree of
MASTER of Media Design

Gilang A. Pradana

Thesis Committee:

Professor Masa Inakage	(Supervisor)
Professor Masahiko Inami	(Co-Supervisor)
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Abstract of Master's Thesis of Academic Year 2013

Ring U: Ring-Shaped Wearable Device for Interpersonal Communication Using Color Lighting and Tactile Expressions

Category: Science / Engineering

Summary

Being able to perceive a variety of emotions has potentially important applications in Computer Mediated Communication (CMC). Many argue that CMC environments inhibit communicating emotional expression. On the other hand, a lot of research related to emotions and non-verbal behaviors has grown rapidly over the last few years. Additionally, some research attempts to create an emotional communication device by adopting color on the system.

In this thesis, as a hybrid approach to place a greater emphasis on existing cues in CMC, the author explores the emotional augmentation benefit of vibro-tactile, color lighting, and simultaneous transmission of both signals to accompany text messages. Ring U, A ring-shaped wearable system aimed at promoting emotional communications in remote communication using the vibro-tactile and color lighting expressions, is proposed as the implementation method. The result of the experiment has shown that these augmented cues can help to stimulate a better assessment to emotional states in a CMC environment.

Keywords:

Verbal and Non-Verbal Communication, Emotion, Vibro-tactile, Color

Graduate School of Media Design, Keio University

Gilang A. Pradana

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Chapter 1
Introduction

1.1. Background and Motivation: Computer Mediated Communication

Our ability to express and accurately assess emotional states is important to our life. Being able to perceive a variety of emotions also has potentially important applications in Computer Mediated Communication (CMC) [13] . There is an empirical question regarding the communication of emotion, for example if it is possible to understand emotional information in a computer-mediated environment, where it adopts characters in text, and sometimes extended to audio-visual cues, to share their in-formation. Research in Social Presence Theory states that less rich CMC environments inhibit communicating emotional expression, while in much richer environments in which non-verbal cues are available, a full range of emotional information can be communicated due to greater social presence [30].

On the other hand, a lot of research has been done worldwide to examine the relationship between emotions and nonverbal behaviors, for example, the area of haptic human computer interaction, which has grown rapidly. A range of new applications has become possible that touch can be used as an interaction technique.

The same perception as is possible in face-to-face communication, where both verbal and non-verbal cues are available, is also expected in CMC environment. A theory (Social Information Processing, SIP; [34]) proposes that interpersonal cues, such as emotional information, are present in computer-mediated environments,

but it just takes longer to derive the same information. Therefore, there is a need to place a greater emphasis on existing cues by developing a new strategy in CMC environment.

Another approach to support the emotional assessment in CMC environment is to adopt colors on the system. Color-emotion relationship has been increasingly researched in recent years. Previous empirical studies have shown consistent emotional responses to color, across a variety of contexts [4] [37] [23] [36]. Following this insight, some research attempts to create emotional communication device by utilizing ambient multi-color glow [17]. Considering the strong relationship between color and emotion, the author believes that this approach can be adopted as an extra channel to strengthen the cues in CMC environment.

1.2. Proposed Interface

In this thesis, as a hybrid approach in attempt to place a greater emphasis on existing cues by developing a new strategy in CMC environment, the author explores the emotional augmentation benefit of vibro-tactile, color lighting, and simultaneous transmission of both signals to accompany text messages. The aim is to study the relationship and the benefit of utilizing both verbal and non-verbal channel on emotional response in Computer Mediated Communication.

Advances in mobile wearable technology have made the author believe that there is a need to implement the idea into a compact wearable device. Ring U, A ring-shaped wearable system aimed at promoting emotional communications in remote communication between people using the vibro-tactile and color lighting expressions, is proposed as the implementation method. Traditionally, a ring has been used as a symbolic present to deliver a message from the sender (the one who gives present), to the receiver. A ring is one of the fashion accessories between couples to represent their relationships. Using this metaphor, the author believes that a ring is a perfect symbol of something emotionally close and connected,

which fits really well with RingU aim to create a communication system that makes users feel even more connected and emotionally close.

The RingU system consists of a wearable ring-shaped device and a smart phone. When a user squeezes the ring, a signal will be sent via bluetooth low energy to his/her smartphone, and then through the internet to his/her partner 's system, and it allows a virtual mini-hug and color to be sent to a paired partner 's ring. For that very instant, they will feel each other 's warm presence. The result of the experiment has shown that these augmented cues can help to stimulate a better assessment to emotional states in a CMC environment. The emotional perception of a text message can be driven to higher valence with a positive stimuli, and lower valence with a negative stimuli.

1.3. Contributions of This Thesis

In this thesis, a scientific study was conducted. The author explored the emotional augmentation benefit of vibro-tactile, color lighting, and simultaneous transmission of both signals to accompany text messages. The aim is to study the relationship and the benefit of utilizing both verbal and non-verbal channel on emotional response in Computer Mediated Communication. From the experiment, we can conclude that both positive touch and positive color stimuli can invoke a more positive valence, especially in positive color stimuli, where it has more effect to convey positive emotion. On the other hand, both negative touch and negative color stimuli can invoke a more negative valence, as it is expected in the hypothesis. However, another findings from the experiment is that compared to the effect on valence, touch stimulus has more effect on the activity level, especially for the negative touch stimuli, which has most tendency compared to other stimulus, to invoke a higher activity level and slightly more negative valence. This thesis has the contributions to show the effect of augmenting two different non-verbal cues to accompany verbal cue in text messages, and to prove that touch

and color stimuli is effective to invoke and change the emotional perception to a text message. It has also shown in details about the tendency of emotional perception change of each non-verbal cues.

1.4. Thesis Organization

The remainder of this thesis is organized as follows. In Chapter 2, research background and related work on tactile interaction, color, and emotion are described. Chapter 3 describes the hybrid approach and concept to achieve the author 's goal. In Chapter 4, the hardware and software implementation of the system is described. In Chapter 5, how the system was evaluated, including scientific study and its result, will be explained, and its discussions will be presented in Chapter 6. In the last chapter, conclusions and directions for further work are offered.

Chapter 2
Related Works

2.1. The Importance of Touch Sense and Tactile Communication System

A lot of research has been carried out worldwide to examine the relationship between emotions and nonverbal behaviors. For example, the area of haptic (touch-based). Human touch has a long history in healing and medical therapy. In ancient Greece, Hippocrates (ca 460370 BC), the father of Western medicine, hailed " rubbing " as an important physician 's skill [16] [14]. Modern empirical work has also shown that human touch in massage reduces stress hormones and increases the circulation of chemicals that counteract physiological arousal [21]. Simple touches, such as holding hands or tapping another 's forearm, can dispel the threat and promote calm. [8].

Touch based interaction in Human Computer Interaction (HCI) has grown rapidly over the last few years. A range of new applications has become possible now that touch can be used as an interaction technique. One example of a system that uses tactile information is ' inTouch '[1] first described in 1997. It introduced the method of applying haptic feedback to interpersonal communication providing a physical haptic link between users separated by distance. Another example is comTouch. ' comTouch ' [2] was designed to enhance the expressive capacity of a communication held between two people on a mobile phone, by the addition of a direct pressure-to-vibration mapping between devices (Figure 2.1). Another early works like HandJive has proven a concept of a handheld object that

allows remote play through haptic input and output [10].

Another related field called Affective haptics focuses on the study and design of systems that can enhance the emotional state of a human by means of the sense of touch. One example is in Kusuguri, where visual tactile integration for tickling is proposed [11]. Another example is in huggy pajama, which aimed at promoting intimate physical interaction between parent and child [33]. Rehman and Liu from Digital Media Lab in Sweden have proposed iFeeling interface, where they implemented vibro-tactile rendering of human emotions on mobile phones, and has shown a potential to enrich mobile phones communication among the users through the touch channel [18]. Another paper discovered about our readiness to empathize with and support that person by being touched by another person influences, and suggests that touch seems to be a special sensory signal that influences recipients in the absence of conscious reflection and that promotes pro social behavior [28]. In a more human-like form, Hiroshi Ishiguro has introduced a portable human-like robotic avatar called " Elfoid " which is designed to convey individuals ' presence using voice, human-like appearance, and touch [20] (Figure 2.1).

However, the design of easily understandable haptic symbols is a difficult process that requires far more research, as stated by Rovers and van Essen [26]. Previous research has shown that a touch by another person can elicit strong affective experiences. If the touch metaphor proves to be valid and it is still highly speculative, tactile must be examined for controlled experiments on how people respond to and experience being touched by another person. This field needs to be empirically established and grounded within a multidisciplinary theoretical framework that encompasses multi-sensory perception and communication theory. Some of the previous papers have also suggested that in face-to-face communication we experience and got affected by more than one verbal cues and non-verbal cues. Therefore, there is a need to place a greater emphasis on utilizing both verbal and non-verbal cues simultaneously in CMC environment, as it is possible

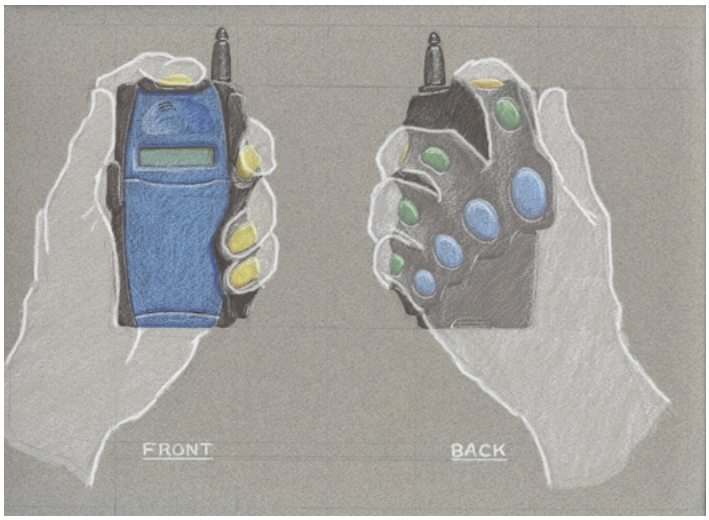

Figure 2.1: ComTouch Concept drawing showing a handheld sleeve that fits onto the back of a mobile phone

Figure 2.2: Portable human-like robotic avatar “ Elfoid ”, designed to convey individuals ’ presence

in face-to-face communication.

2.2. Emotion in Text-Based Communication

Modern interpersonal communication technologies adopt characters in text to share their information. In this thesis, there is also a need to study on related research about how emotion is assessed in text-based communication, where non-verbal cues thought to carry emotional information is eliminated.

One example is a study from Gill, et. Al. , where they study about emotion rating from short blog texts [13]. They explore the text-based communication of emotion in CMC, and examine whether emotion can be accurately classified on the basis of asynchronous short blog text extracts derived from real emotional blogs. Another example is from a research by Hancock, et. Al., where they examined how people express and detect emotions during text-based communication [15]. This research has shown that emotional information is present in text-based communication, but it still leaves space for the augmentation of another cues to stimulate a better assessment to emotional states.

2.3. Color-Emotion Related Research

Another approach to support the emotional assessment in CMC environment is to adopt colors on the system. For centuries artists have been exploring color to express emotions, and color-emotion relationship has been increasingly researched in recent years.

Previous empirical studies have shown consistent emotional responses to color, across a variety of contexts [4] [37] [23] [36]. Another study from University of Science and Technology of China has also adressed about the relationships between color attributes and emotional dimensions by classification based on associations, where they also predicted subjects' emotional response to a new color from their

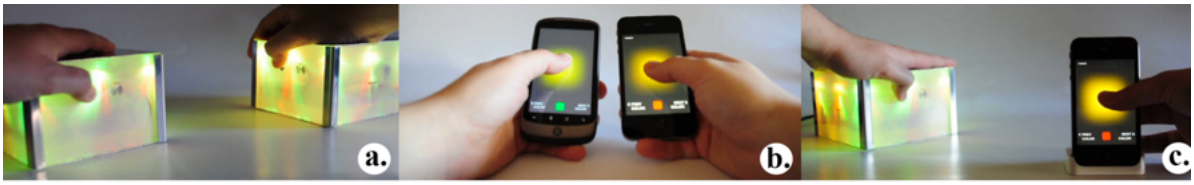

Figure 2.3: cubble 's hybrid interaction (holding hands). a. hardware only. b. mobile only. c. hardware and mobile combined.

finding [6]. Cultural background also influenced the color-emotion relationship. A study about cross-cultural color emotion has shown that chroma and lightness were the most important factors on color emotion, whereas the influences of hue and cultural background were very limited [12].

Following these insights, some research attempts to create emotional communication device by utilizing ambient multi-color glow, like in LumiTouch [3]. We can also see one example in one released product by Phillips, Hue, where you can control your room lighting based on your mood. Considering the strong relationship between color and emotion, the author believes that this approach can be adopted as an extra channel to strengthen the cues in CMC environment. Wisneski investigated the design of small personal ambient displays, worn to display information to a person in a subtle, persistent, and private manner [35]. Researchers at Osaka University has proposed a soft social-touchable interface called " Emoballoon " that can recognize the types of social touch interactions, which consists of a balloon and some sensors including a barometric pressure sensor inside of a balloon, and has a soft surface and ability to detect the force of the touch input and show the emotion with the baloon as an ambient color display [22]. Another example, cubble, has tried to adopt this hybrid approach by creating colors and haptic tap patterns as ambiguous and self-assignable message and emotion templates for intimate communication in a form of cube [17] (Figure 2.3). However, this research does not address how this hybrid approach is beneficial to the emotional state

assessment, which is important in interpersonal communication.

This thesis has a novel contribution to prove the concept of a hybrid approach in attempt to place a greater emphasis on existing cues by developing a new strategy in CMC environment. By exploring the emotional augmentation benefit of vibro-tactile, color lighting, and simultaneous transmission of both signals to accompany text messages, This thesis has shown the effect of augmenting two different non-verbal cues to accompany verbal cue in text messages, and to prove that touch and color stimuli is effective to invoke and change emotional perception to a text message. It has also shown in details about the tendency of emotional perception change of each non-verbal cues.

Chapter 3
RingU : Ring-Shaped Wearable Device as a Hybrid Approach in Computer Mediated Communication

In this thesis, as a hybrid approach in attempt to place a greater emphasis on existing cues by developing a new strategy in CMC environment, the author explores the emotional augmentation benefit of vibro-tactile, color lighting, and simultaneous transmission of both signals to accompany text messages. The aim is to study the relationship and the benefit of utilizing both verbal and non-verbal channel on emotional response in Computer Mediated Communication.

Advances in mobile technology have enabled us to effectively interact with mobile devices to do our task, mainly communication, regardless of the place. Recent technology has also made it possible to package a communication device into a range of wearable devices. Latest invention like Smart Watch[13], only tries to make a device in a smaller size without adding some cues convey emotional expression in communication. This makes the author believe that there is a need to implement the idea to place a greater emphasis on existing cues by developing a new strategy in a CMC environment into a compact wearable device.

Ring U, a ring-shaped wearable system aimed at promoting emotional communications in remote communication between people using the vibro-tactile and color

lighting expressions is proposed. Traditionally, a ring has been used as a symbolic present to deliver a message from the sender (the one who gives present), to the receiver. A ring is one of the fashion accessories between couples to represent their relationships. A ring is an unbroken circle, which many cultures understand as the representative of eternity, which symbolizes the eternized promise between them on their engagement and wedding. The ring can acts as a reminder and an outward symbol to others that a person is currently on an eternal commitment.

Not only for couples, ring also has a meaning as a source of unity. People wear rings to join others and symbolise that they are in the same cause. We can see some examples of the use of a purity ring, or when a group of supporters wear rings after the victory of their team. Using this metaphor, the author believes that a ring is a perfect symbol of something emotionally close and connected, which fits really well with RingU aim to create a communication system that makes users feel even more connected and emotionally close.

Figure 3.1: Squeezing the ring to send a lighting and a vibro-tactile signal to the paired partner.

The RingU system consists of a wearable ring-shaped device and a smart phone. When a user squeezes the ring, a signal will be sent via bluetooth low energy to his/her smartphone, and then through the internet to his/her partner 's system, and it allows a virtual mini-hug and color to be sent to a paired partner 's ring. For that very instant, they will feel each other 's warm presence. (Figure 3.1)

As described in the previous chapter, ambient multi-color glow has adopted in some research to create a certain mood and emotional feeling. The same approach was implemented into the wearable ring, along with the vibro-tactile, which acts as a non-verbal cue in the communication channel (Figure 3.2). This proposed interface is used to conduct our study about the relationship and the benefit of utilizing both verbal and non-verbal channel on emotional response in Computer Mediated Communication.

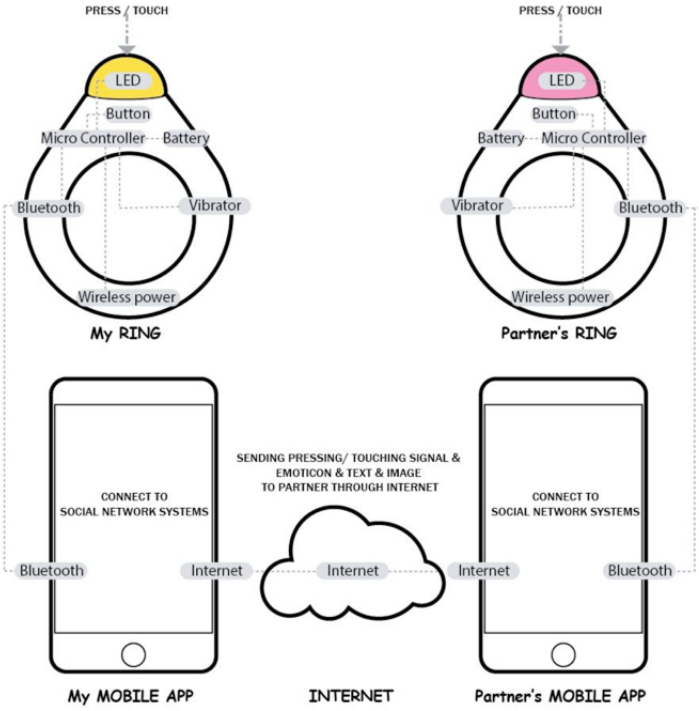

Figure 3.2: RingU System Scheme

Chapter 4
System Implementation

4.1. Hardware Implementation

Several prototypes have been developed as an implementation of RingU. The first prototype of RingU system is designed for the proof of concept and it consists of a processor, a push button, an RGB LED, a vibration motor, a XBee module, and a battery. Due to time and hardware limitation, the author has not been able to create a tiny electronic circuit which can fit into a size of a ring. Hence, for the prototype, the push button, the LED, and the vibration motor were built into the ring and a separated box that is connected with a wire with the ring has been designed to contain comparatively bigger modules such as the processor, the Xbee, and the battery (Figure 4.1).

Figure 4.1: RingU first prototype

The outer case of this prototype, including the ring and the box, was made from a 3D printed ring-shaped model. The 3D design was designed using a computer software (Figure 4.2). Arduino FIO[1], a functional prototyping microcontroller, has been used in the prototype, considering of its compatibility with XBee module, a module used for wireless communication[2]. This prototype consists of a pair of two ring devices that communicates directly to each other through a XBee module. This limits the prototype to work only in a limited range due to the XBee module limitation An electronic circuit was designed to integrate all the electrical components in this prototype (Figure 4.3). The input component (push button), and the output components (RGB LED and motor) were connected to pins provided by Arduino FIO A LIPO battery is connected to the microcontroller to enable the prototype to work as a wireless stand alone device (Figure 4.4).

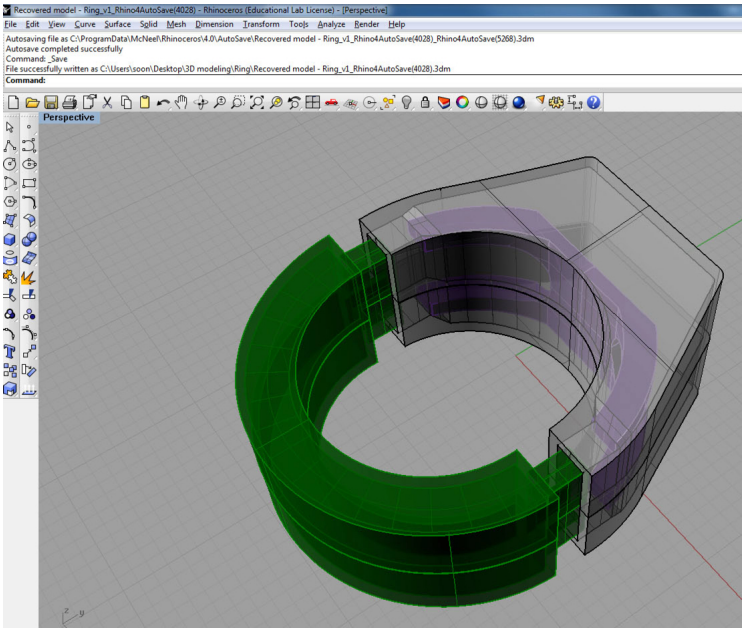

Figure 4.2: Computer generated 3D model for RingU

In this thesis, the author focuses to explore the emotional augmentation benefit of vibro-tactile, color lighting, and simultaneous transmission of both signals to

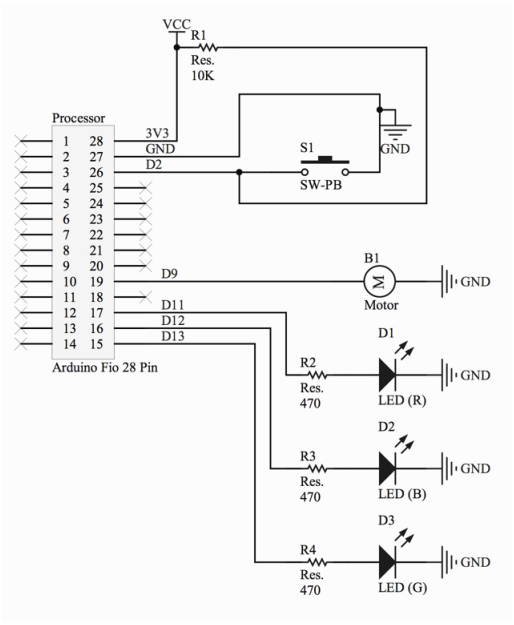

Figure 4.3: RingU schematic design

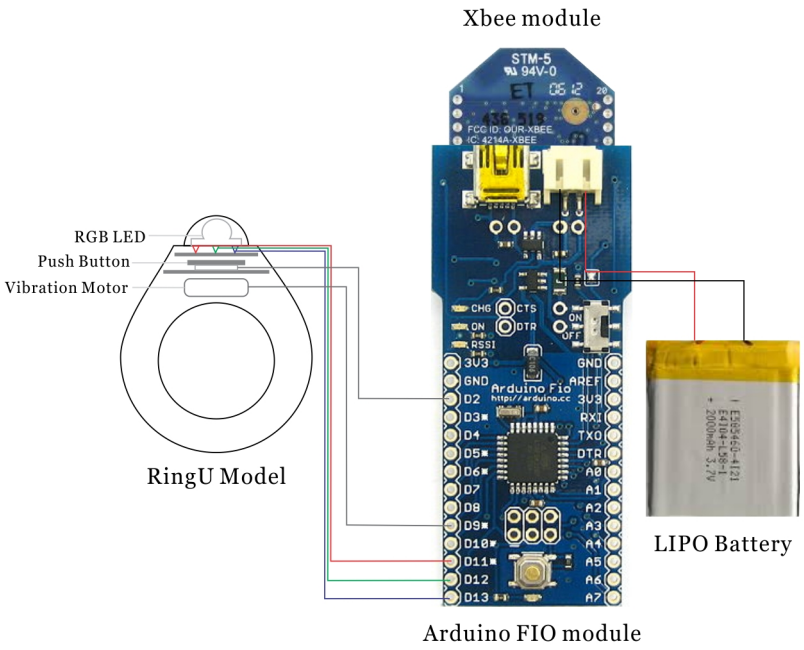

Figure 4.4: RingU first prototype hardware configuration

accompany text messages. Due to the limited connectivity of the first prototype, we could not modify the ring to give a specific vibro-tactile pattern or LED color simultaneously with text messages in real time for the scientific study purpose. Hence, there is a need to build another prototype for the ring that can communicates with a database server to simultaneously send text messages along with the vibro tactile or color stimuli, and also able to record the emotional response of the stimulus.

The same 3D printed ring-shaped model with a built-in input and output components (RGB LED motor) was also used in this prototype. An Arduino UNO[3], which is also a functional prototyping microcontroller, was used in this prototype. This microcontroller can be connected to a PC which allows the author to program a software that can connect to a message database server to simultaneously send text messages along with a specific vibro tactile or color stimuli (Figure 4.5). A different electronic circuit was designed to adapt the change of the microcontroller, since they are using a different pin scheme.

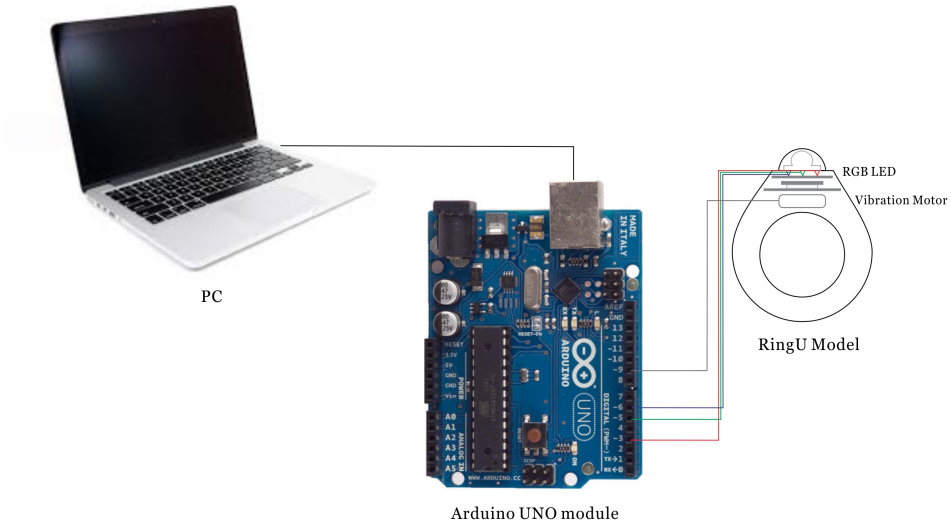

Figure 4.5: RingU prototype hardware configuration for scientific experiment purpose

The author only contributes in the small part of the hardware implementation

in the RingU project. The contribution includes building the prototype for the scientific study purpose. The first prototype was mainly developed and built by Yongsoon Choi, who is a graduated Ph.D. Student from the Graduate School of Media Design, Keio University. The development of the prototype for scientific study purpose was done together with Jordan Tewell, who is a former Ph.D. student from the same university.

4.2. Software Implementation

To make a fully functional hardware, there is a need to develop a software which controls the behavior of all the components of the hardware. In the first prototype, the software was developed in a standard Arduino sketch[4] to control the components connected to an Arduino FIO microcontroller. The main function of this software is to declare the pins used and connected to the input and output components, and to change communicate with partner's XBee module to change its state as the button is pressed, so that the output components can react to the state changes.

Arduino sketch can be developed with the official Arduino Integrated Development Environment (IDE), and it allows us to, for example, define which hardware is currently connected to a certain pin, and control either to turn on or turn off each component. In this sketch, we are controlling the LED and motor to turn on when the button on partner's ring is pressed, and turn them back off when the button is no longer pressed. A default procedure in Arduino programming to turn the state of a certain pin to high and low was used for all components: red LED pin, green LED pin, green LED pin, and motor, so there is no certain control of which color to show and in what pattern and power should the motor work (Figure 4.6). The source code for the arduino sketch is attached on the appendix.

For the scientific study purpose, A web based application was developed, which enables to load a specific text message from the database and records partici-

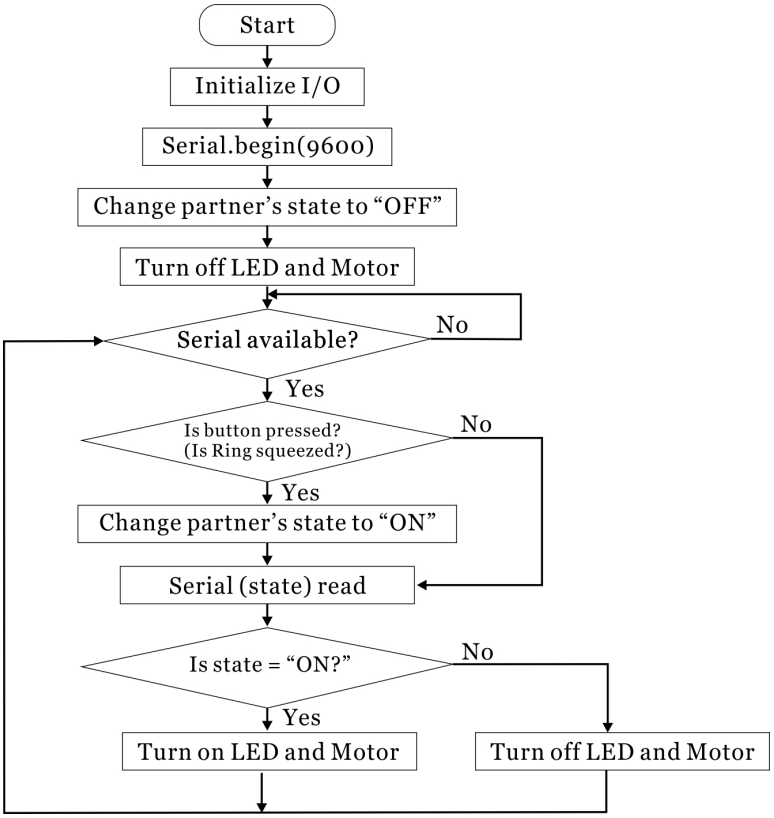

Figure 4.6: RingU first prototype Arduino sketch flowchart

pant responses in real-time (Figure 4.7). An additional component called BreakoutJS[5] was used to enable a web application communicates with an Arduino board. This web application's main function is to load a specific text message from the database, and send it to the participant simultaneously with a vibro-tactile pattern or color lighting stimuli from the ring. This web application also shows the emotion wheel to enable participants to rate their emotional responses and save them to the response database (Figure 4.8).

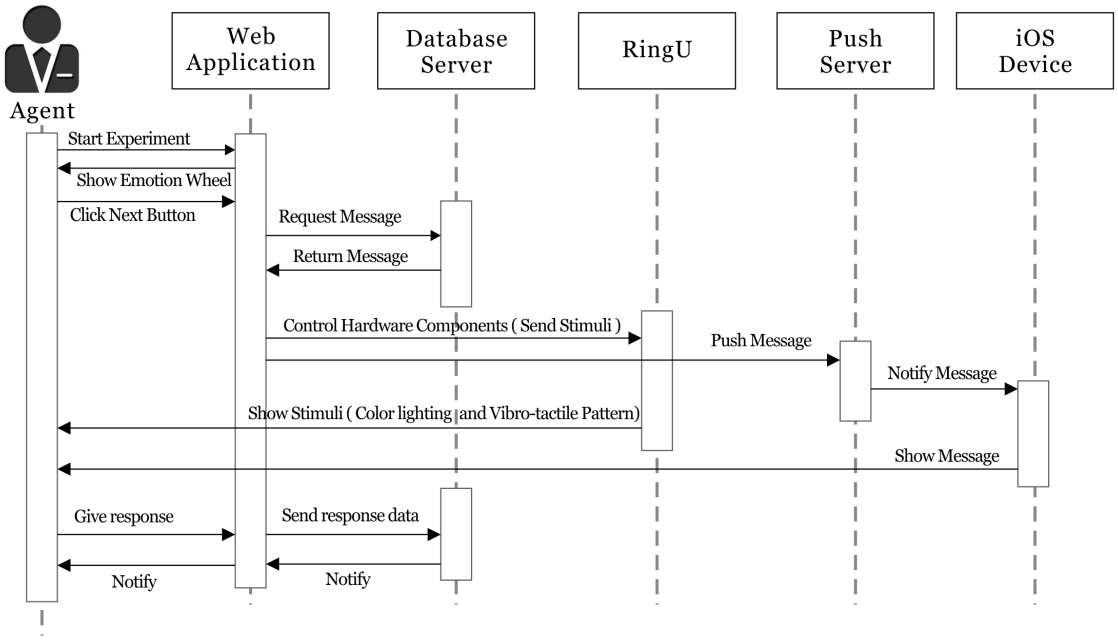

Figure 4.7: RingU scientific study sequence diagram

On the server side implementation, a newly launched service, Parse, was used. This service aims to be the back-end solution for a system, which allows developers to focus more on the front-end development and user interface[6]. Its compatibility and ease to implement into projects is the main reason for why this service was used. Another server side service which was being utilized is called PubNub[7]. This service focus on delivering push service, which was needed to push the mes-

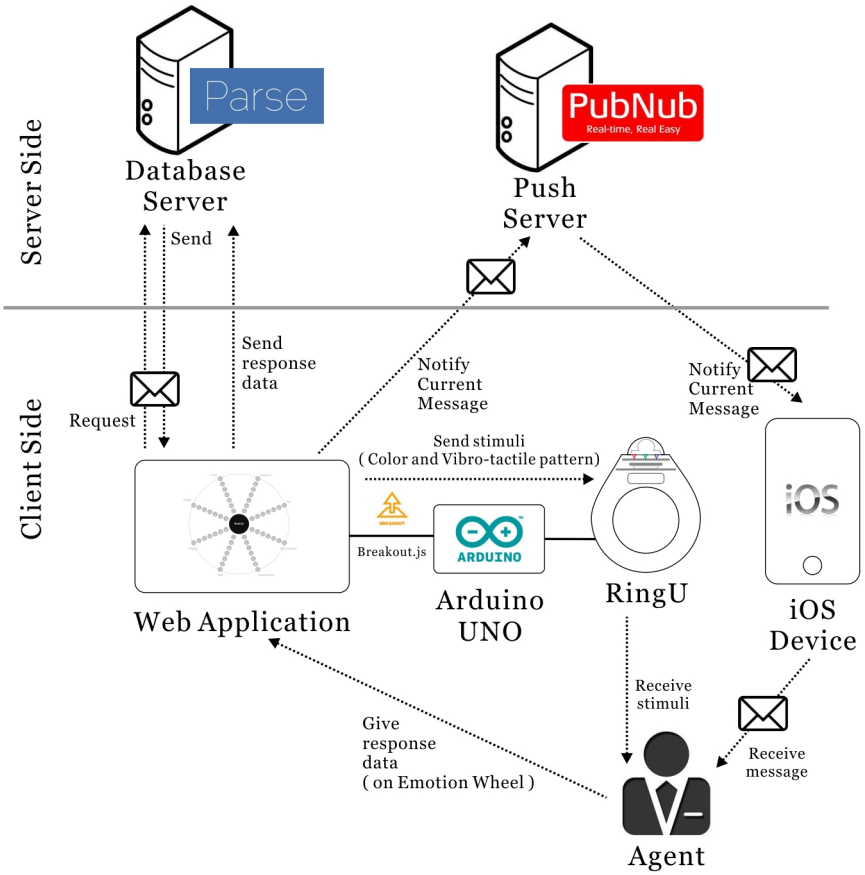

Figure 4.8: RingU implementation for scientific study

sage from the database, and deliver it in real time to the iOS device that the participants use for the experiment. The full source code for the web application is attached on the appendix.

The author contributes mainly on the software implementation and research contribution in the RingU project. The contribution includes controlling the behavior of all the components of the hardware, setting up a web server and database for the experimental purpose, and developing a web application for the experiment.

Notes

1 http://arduino.cc/en/Main/ArduinoBoardFio

2 www.digi.com/xbee/

3 arduino.cc/en/Main/arduinoBoardUno

4 arduino.cc/en/Tutorial/Sketch

5 breakoutjs.com/

6 https://parse.com/

7 www.pubnub.com/

Chapter 5
Scientific Study: Vibro-Tactile and Color Lighting Augmentation Benefit on Emotional Response to Text Messages

This thesis aims to study the relationship and the benefit of utilizing both verbal and non-verbal channel on emotional response in Computer Mediated Communication. In our proposed interface, text message acts as a verbal cue, while color and vibro-tactile stimuli act as non-verbal cues. This is a hybrid approach in attempt to place a greater emphasis on existing cues in CMC environment. In this scientific study, the author explores the emotional augmentation benefit of vibro-tactile, color lighting, and simultaneous transmission of both signals to accompany text messages. The hypothesis of this study is: Augmentation of vibro-tactile, color, or both stimulus affect the emotional perception to a text message. The emotional perception of a text message can be driven to higher valence with a positive stimuli, and to lower valence with a negative stimuli.

5.1. Evaluation Settings

Two experiments, a pre-evaluation experiment, and a main lab based experiment, were conducted for this scientific study. In each of these tests, each par-

ticipant was assigned to rate their emotional responses correspond to message, vibro-tactile, and color lighting stimulus using an emotion wheel evaluation system.

The author expands the classification of emotion from positive and negative into eight main categories as proposed by the literature [9] [25]. The emotion wheel covers joy, surprise, fear, anger, disgust, sadness, acceptance, anticipation, and neutral feeling, with 7 different strengths of each emotion. All participants used the activation-evaluation wheel. Imagining x- and y-axis: Evaluation (valence) is on the x-axis, with positive values on the right, and activity on the y-axis, with high activity at the top and low activity at the bottom. The strength of emotion corresponds to the distance from the center of the circle (between 1 and 7), with the center of the circle used to score 0 or ‘ neutral ’ emotion (Figure 5.1). This model is considered well suited to computational work [5], has previously been used for rating emotion in speech [19], and allows comparison with findings for valence [15]. Alternative approaches to emotion is described in [7] [27]. Two different groups of individuals were gathered for the pre-evaluation experiment and the main lab based experiment.

5.2. Pre-Evaluation Experiment

The pre-evaluation experiment was conducted in order to sort out the color, vibro-tactile stimulus, and messages that were linked to invoke a specifically positive, negative, or neutral valence feeling when accessed to an individual. This experiment consists of three individual parts: Emotional rating of texts, emotional rating of color, and emotional rating of touch. Selected stimulus from the result will be used as the stimulus for the main experiment.

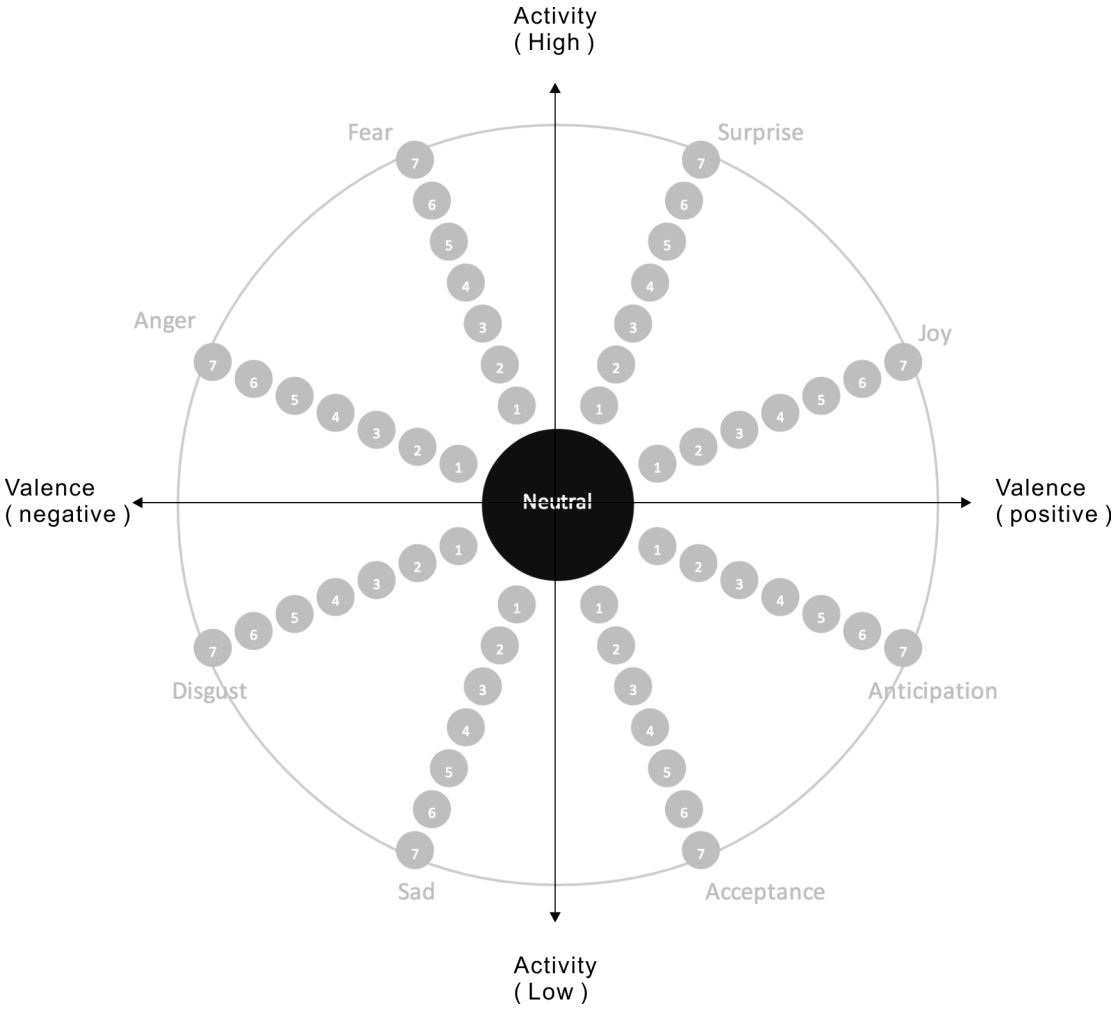

Figure 5.1: Emotion Wheel

5.2.1 Emotional Rating of Text Messages

A list of text messages gathered by a previous study was being used in this experiment [32]. 110 of the most appropriate text messages that fully understandable and non-offensive was chosen. Both English and Japanese translations of these messages are provided and saved into a database. The full list of the messages is attached on the appendix. A web script which would randomize the order of which to send to the testers and displayed them one by one on the webpage was programmed and being used as a part of the evaluation system. After the message was displayed the tester was asked to rate them using the emotion wheel. Once the tester made a selection, they would click the next button, which would display a new message and reset the emotion wheel form (Figure 5.2).

The goal of this was to narrow down the messages to three most dominantly invoked emotion-specific messages to be used in the main lab based experiment: one message for each of the positive, neutral, and negative emotions. A group of 20 individuals were tasked with sorting out the messages. For this part of the experiment, the testers were allowed to examine the messages in the comfort of their own time and leisure, and thus did not have to come to the lab. They logged on to the website and filled in their name, after which they would complete the test.

To narrow down the messages, the emotional responses of the messages have been analyzed using two methods. The first method is to count the number of responses based on the category of positive, neutral, and negative valence. Based on the emotion wheel, the positive value of valence consists of emotions located on the right side of x-axis, and the negative value of valence consists of emotions located on the left side of x-axis. The strength of emotion rating (1-7) for this method was ignored. The second method is the valence analysis method. In this method, the strength of each emotional response (range 1 to 7) was taken, and negative valence emotion scores were multiplied by -1, neutral score was counted as 0, and the scores for each text message are summed. The full list of 110

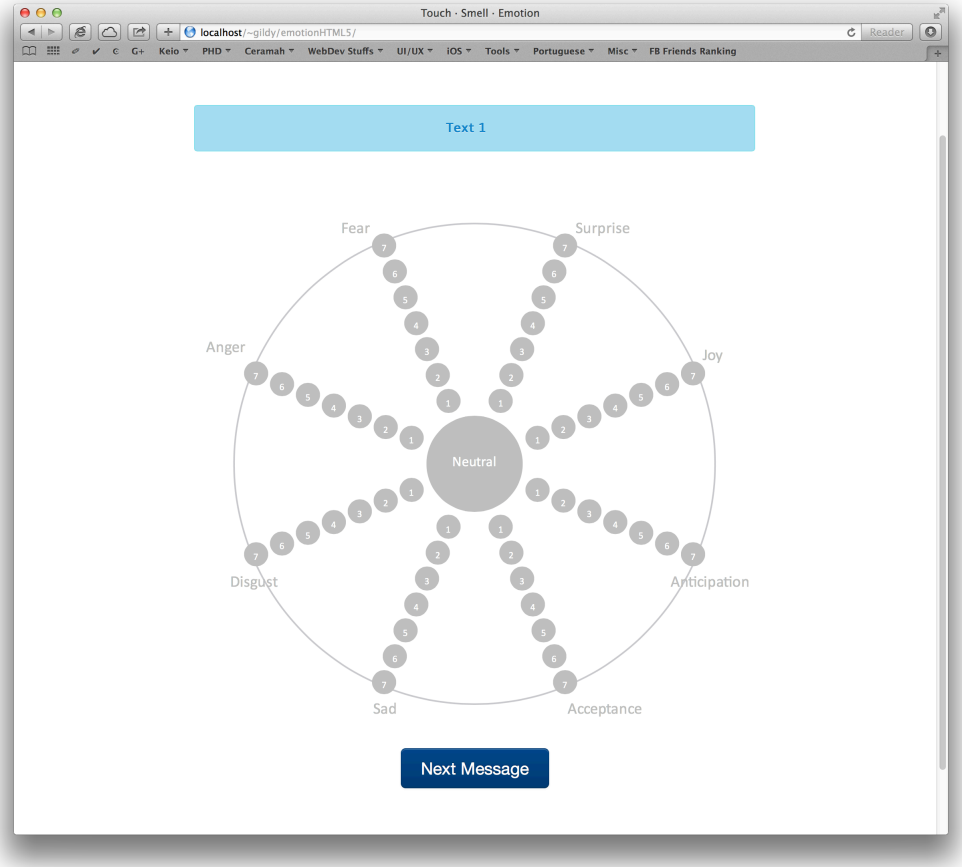

Figure 5.2: Emotion Rater Web Application

text messages with it responses will be listed on the appendix. The result of the narrowed down messages is as follows:

Table 5.1: Emotional rating of texts experiment result

Message	+	O	-	Value
Yay! Finally lol. I missed our cinema trip last week	20	0	0	96
At home by the way	6	6	8	-6
No, but you told me you were going, before you got drunk!	1	0	19	-62

The result has shown that for the selected positive message, all 20 participants agreed that this message convokes a positive emotional response. This message also has the highest valence analysis value. The selected neutral message has the most balanced responses of positive, neutral, and negative emotion, with the valence analysis value close to 0. In the selected negative message, 19 out of 20 participants agreed that this message convoke a positive emotional response, with the lowest valence analysis value of -62.

5.2.2 Emotional Rating of Colors

A set of 11 colors was selected from previous research based on their relation to emotion. A study by Manning, et. Al., examined the relationship between color and emotion [24]. Similar to the emotional rating of text, a web script would randomize the order of which color to send to the testers and displayed them one by one on the Ring U. After the color light was displayed, the tester was asked to rate them using the emotion wheel. Once the tester made a selection, they would click the next button on the emotion rater screen, which would send a new color and reset the emotion wheel form. The goal of this was to narrow down to two most dominantly invoked emotion-specific colors to be used in the main lab based experiment: one color for each of the positive and negative emotions.

To narrow down the colors, the emotional responses of the color have been analyzed using two method of categorizing responses and valence analysis used in the previous emotional rating of text experiment. The result of the emotional response of 11 color stimulus is as follows:

Table 5.2: Emotional rating of colors experiment result

Color	+	O	-	Value
White (Hex: FFFFFF)	16	2	2	55
Red (Hex: CC0000)	9	0	11	-36
Orange (Hex: FF9900)	20	0	0	94
Light Orange (Hex: FFCC00)	18	0	2	54
Yellow (Hex: FFFF00)	16	0	4	49
Green (Hex: 009900)	16	1	3	46
Cyan (Hex: 00CC99)	12	0	8	12
Blue (Hex: 0000FF)	0	0	20	-81
Dark Blue (Hex: 000066)	10	0	10	-9
Purple (Hex: 660099)	9	0	11	0
Pink (Hex: CC0066)	16	0	4	52

The result has shown that all 20 participants agreed that orange (Hex: FF9900) convokes a positive emotional response and blue (Hex: 0000FF) convokes a negative emotional response. The same result is also shown in the valence analysis, with the highest value of 94 for orange and lowest value of -81 for blue. The neutral category for color was not selected because the color stimuli will be used to augment the emotional perception of a text message, so it needs to have a certain emotion.

5.2.3 Emotional Rating of Touch

Lastly, a test of different types of vibrations from our ring device to the participants was conducted. There were two parameters controlled: The time duration

from 1 second to 5 seconds at 1 second interval, and the intensity of the vibration, which was achieved by altering the duty cycle of the Pulse Width Modulation wave sent to vibration motor inside the ring. Duty cycle describes the proportion of how much power is currently running: a low duty cycle corresponds to low power, because the power is off for most of the time, and a high duty cycle corresponds to high power. Duty cycle is expressed in percent, 100% being fully on. This was set at 20%, 40%, 60%, 80%, and 100% duty cycles. From these 5 values for two parameters, 25 unique combinations which each user tested were obtained. A “ 0 ” vibration with 0 duty cycle and 0 sec duration as a 26th neutral vibration. These vibrations were randomized and sent to the user sequential-ly after the users made their choices on the emotion wheel. After the test, two vibrations for each emotional category of positive and negative were selected.

To narrow down the vibro tactile stimulus, the emotional responses of the stimulus have been analyzed using two methods of categorizing responses and valence analysis used in the previous emotional rating of text experiment. The result of this touch experiment is shown on Table 5.3.

This result has shown that only controlling two parameters of length and intensity are insufficient, and resulted in bias. Some comparatively dominant results to be selected for the main experiment can barely seen. The author decided to adopt the tactile pattern mapped to emotional expression introduced by Shin, et. Al in their study [29]. This set of patterns was used, together with the two most dominant result of the first touch experiment and a ”0” vibration, to get more clear result (Table 5.4). To implement these patterns in RingU, a timer was set to alter the duty cycle of the motor after a certain period of time. Similar to the emotional rating of text and color, a web script would randomize the order of which pattern to send to the testers and displayed them one by one on the RingU. After the pattern was sent, the tester was asked to rate them using the emotion wheel. Once the tester made a selection, they would click the next button on the emotion rater screen, which would send a new pattern and reset the emotion

wheel form. The goal of this was to narrow down to two most dominantly invoked emotion-specific vibro-tactile patterns to be used in the study: one pattern for each of the positive negative emotions. The result of this touch experiment is shown on Table 5.5.

The result has shown that 18 out of 20 participants agreed that Grin (Quick, Light and Regular vibration) pattern convokes a positive emotional response. The same result is also shown in the valence analysis, with the highest value of 56 for this pattern. On the other hand, 13 out of 20 participants agreed that Cry (Slow Moving vibration: High, weak,mid, and weak stress) and Anger (One strong vibration) patterns convoke a negative emotional response. The valence analysis result shows that the cry pattern has a lower value of -33, so it was selected as the negative vibro tactile stimuli. The neutral category for touch was also not selected because the touch stimuli will be used to augment the emotional perception of a text message, so it needs to have a certain emotion.

5.3. Main Experiment

In the main lab based experiment, the participants were assigned to examine how touch and color can augment the emotional perception to a text message, or how both can affect them at the same time using an emotion wheel evaluation system. 20 participants were asked to join this experiment, and the experiment took about 10 to 15 minutes.

From the pre-evaluation experiment, dominantly invoked emotion-specific stimulus from each category have been selected: Three messages, one for each positive, neutral, and negative emotion, two colors, one for each positive and negative emotion, and two vibro-tactile patterns, one for each positive and negative emotion. In this experiment, the emotional augmentation benefit of vibro-tactile, color lighting, and simultaneous transmission of both signals to accompany text messages was examined. Each of the selected stimulus from the pre-evaluation experiment

will be combined to be transmitted simultaneously to accompany text messages. For each category of text message, there are 9 possible combinations: A text only stimuli, Text with positive, and negative touch, Text with positive, and negative color, Text with positive touch and positive color, with positive touch and negative color, with negative touch and positive color, and with negative touch and negative color. There are three different text categories, which result in total of 27 combinations of stimulus to be examined in this main experiment.

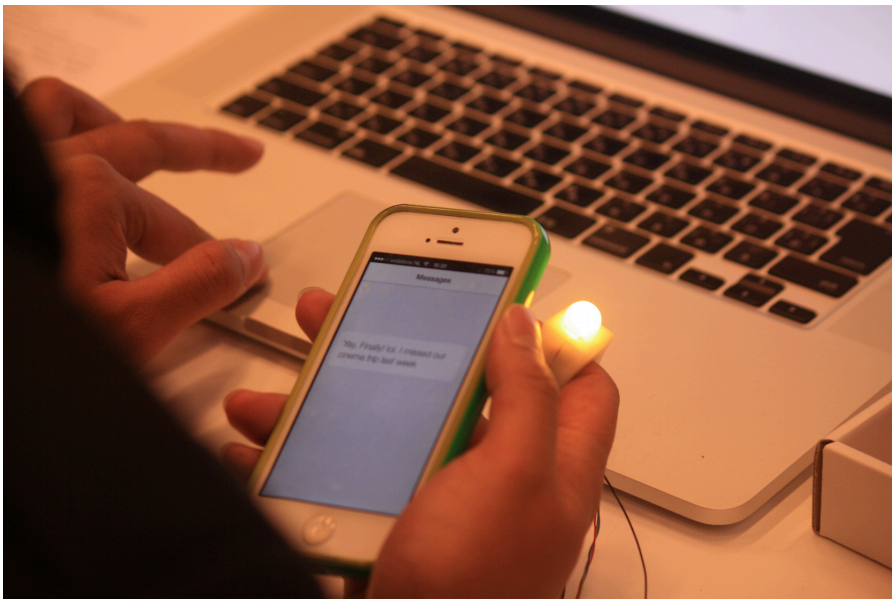

Figure 5.3: Participant wears the ring while holding an iPhone.

The participants were asked to wear the ring on their hand while holding an iPhone, which shows the set of messages they are going to rate (Figure 5.3). The participants were asked to focus on the iPhone screen and the RingU, and were told that there will be messages coming. After receiving each stimuli, they were asked to rate their emotional response in our online emotion wheel rating system, which was used in our previous pre-evaluation experiment. These were recorded into a database entry. Our application would present the user with a button to proceed to the next stimuli once they have recorded the emotion on the emotion

wheel rating system.

As explained earlier in this chapter, the emotion wheel can be mapped into x- and y-axis: Evaluation (valence) is on the x-axis, with positive values on the right, and activity on the y-axis, with high activity at the top. The strength of emotion corresponds to the distance from the center of the circle (between 1 and 7), with the center of the circle used to score 0 or ‘ neutral ’ emotion. The recorded emotional responses were mapped into a scatter chart with x and y axis, both in positive and negative value. The emotional responses result for each stimuli is shown in the figures below. Standard deviation σ_x for valence and σ_y for activity level is also calculated to show how much variation or dispersion from the mean for each type of stimuli.

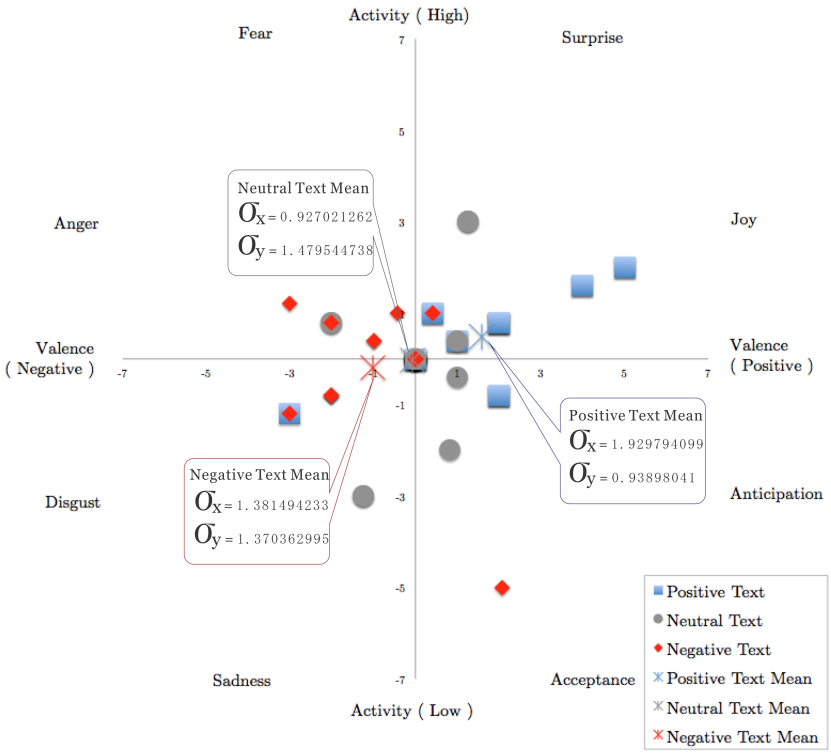

Figure 5.4: Emotional responses in text only stimulus

Figure 5.4 shows the emotional responses in text only stimulus for each message category. Blue squares show responses for positive message, Gray circles

show responses for neutral message, and red diamonds show responses for negative message. Each asterisk symbol in corresponding color shows the mean for each message category. This graph shows that most of the responses for positive messages are mapped on the positive valence area, in slightly high activity level. The mean value for the positive message is mapped in positive valence area with slightly high activity level. For neutral message, most of the responses concentrate in the center of the graph, with some of the responses are mapped in a slightly positive or negative valence. The mean value for neutral message is mapped almost close to the center of the graph. For negative message, most of the responses are mapped on the negative valence area, in slightly high, or low activity level. The mean value for the negative message is mapped in negative valence area with slightly low activity level.

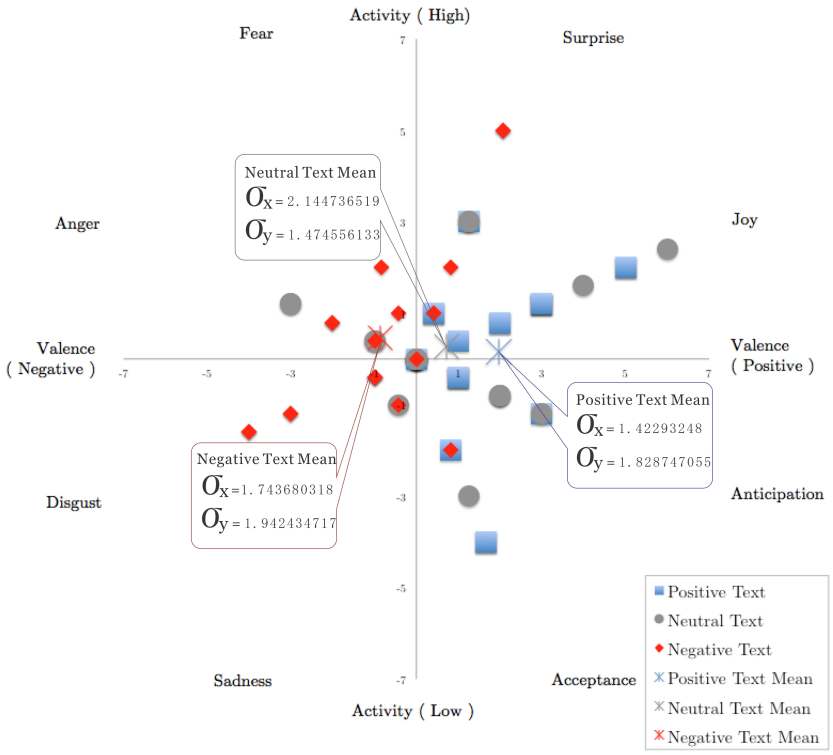

Figure 5.5: Emotional responses in positive touch stimulus

Figure 5.5 shows the emotional responses in the text with positive touch stim-

ulus for each message category. This graph shows that most of the responses for positive messages are mapped on the positive valence area, in more positive valence and slightly higher activity level, or slightly lower activity level for some responses, compared to the text only stimulus. The mean value for the positive message is mapped in positive valence area with slightly high activity level, but more valence compared to text only stimuli. For neutral message, some of the responses concentrate in the center of the graph, while some other responses are driven into the positive valence area, with slightly high activity level. The mean value for this message is mapped in positive valence area with slightly high activity level, and has higher activity value and more valence compared to the text only stimulus. For negative message, most of the responses are still mapped on the negative valence area, in slightly high, or low activity level. The mean value for negative message is still mapped in negative valence area with slightly high activity level, which is higher compared to the text only stimulus.

Figure 5.6 shows the emotional responses in text with negative touch stimulus for each message category. Most of the responses and the mean value for positive messages are still mapped on the positive valence area, in less positive valence and higher activity level compared to the text only stimulus and positive touch stimulus. For neutral message, some of the responses are still close to the center of the chart, while some others dispersed both to the positive and negative valence area with comparatively higher activity. The mean value for this message is mapped in negative valence area, which has less positive valence and higher activity level compared to the text only stimulus and positive touch stimulus. For negative message, the mean value, and most of the responses are mapped on the negative valence area, with higher activity level and more negative valence compared to the previous stimulus.

Figure 5.7 shows the emotional responses in text with positive color stimulus for each message category. This graph shows that most of the responses for positive messages are mapped on the positive valence area, in more positive valence

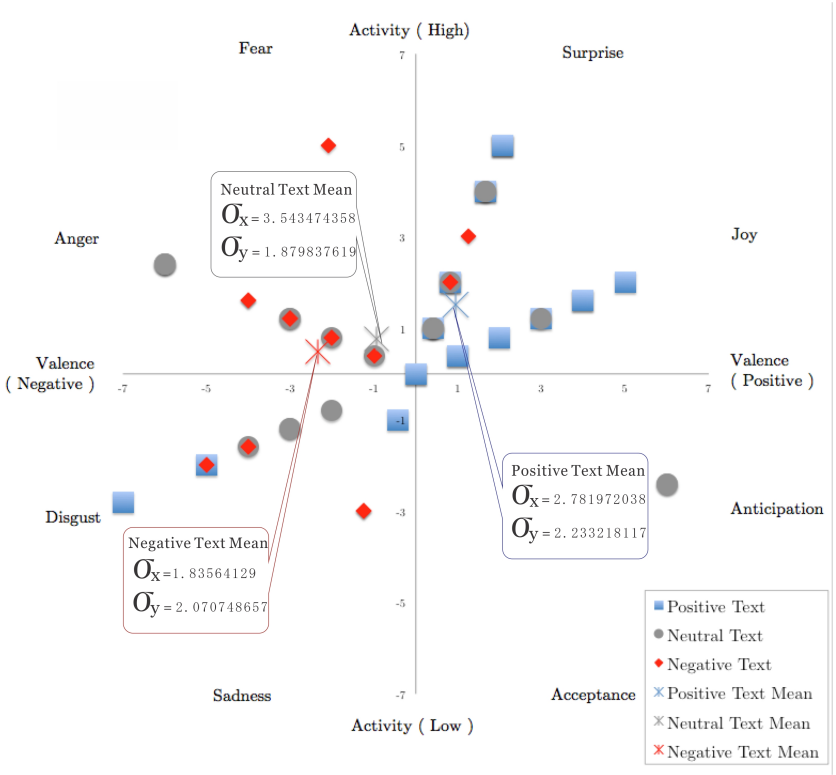

Figure 5.6: Emotional responses in negative touch stimulus

Figure 5.7: Emotional responses in positive color stimulus

and slightly higher activity level compared to the text only stimulus. The mean value for positive message is mapped in positive valence area with more valence compared to the positive touch stimulus, but less higher activity compared to the positive touch stimulus. For neutral message, some of the responses concentrate in the center of the graph, while some other responses are driven into the positive valence area, with slightly higher, or lower activity level. The mean value for this message is mapped in positive valence area with slightly lower activity level and more valence compared to the text only stimuli. For negative message, most of the responses are mapped into the positive valence area, in slightly high, or low activity level. The mean value for negative message is mapped in positive valence area with slightly high activity level and more postive valence compared to the text only stimulus.

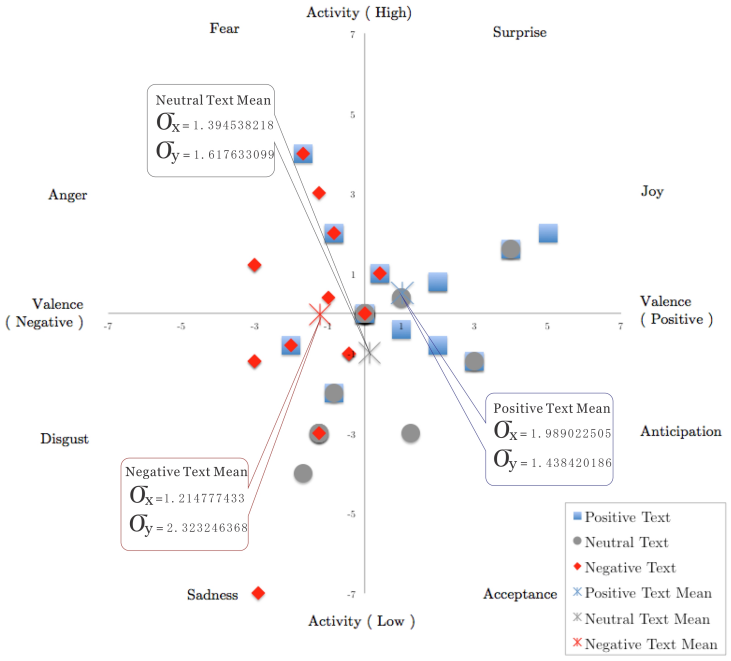

Figure 5.8: Emotional responses in negative color stimulus

Figure 5.8 shows the emotional responses in text with negative color stimulus for each message category. This graph shows that some of the responses for

positive messages are still mapped on the positive valence area, while some other are mapped into the negative valence area, in slightly high activity level. The mean value for positive message is also mapped in less positive valence and lower activity level compared to the text only stimulus. For neutral message, most of the responses are mapped into the negative valence area with slightly low activity. The mean value for this message has less positive valence and lower activity level compared to the text only stimulus. For negative message, most of the responses are mapped on the negative valence area, with higher activity level, or lower activity level for some other responses, compared to the previous stimulus. The mean value for negative message is also mapped in negative valence area, and has more negative valence compared to the text only stimulus, but less negative valence compared to negative touch stimulus, with no significant change in the activity level.

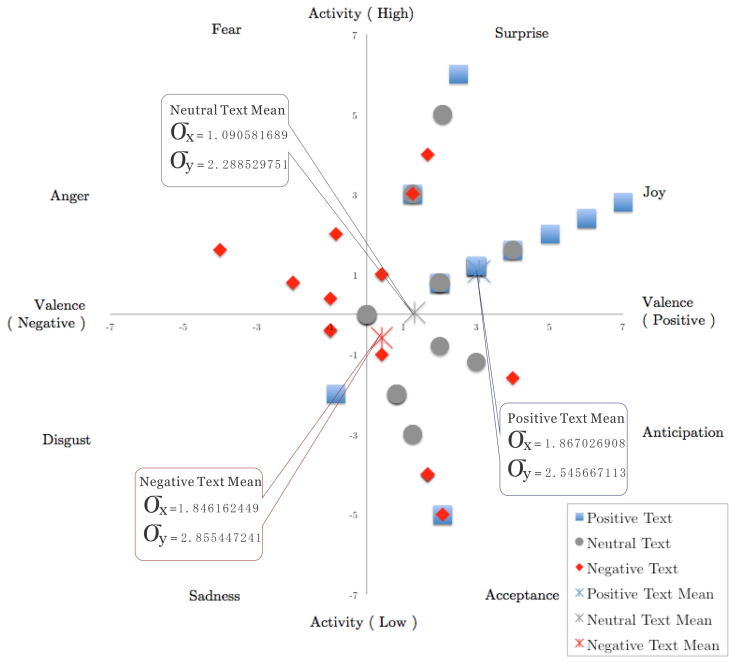

Figure 5.9: Emotional responses in positive touch with positive color stimulus

Figure 5.9 shows the emotional responses in text with positive touch with pos-

itive color stimulus for each message category. This graph shows that most of the responses for positive messages and its mean value are mapped on the positive valence area, in more positive valence and higher activity level, compared to other stimulus. For neutral message, most of the responses are dispersed into the positive valence area, with higher or lower activity level. The mean value for this message is mapped in positive valence area with more valence, but not significant activity level change, compared to the text only stimulus. For negative message, some of the responses are still mapped on the negative valence area in slightly high activity level, while some others are dispersed into the positive valence area, with higher or lower activity level. The mean value for negative message is mapped in positive valence area with slightly low activity level.

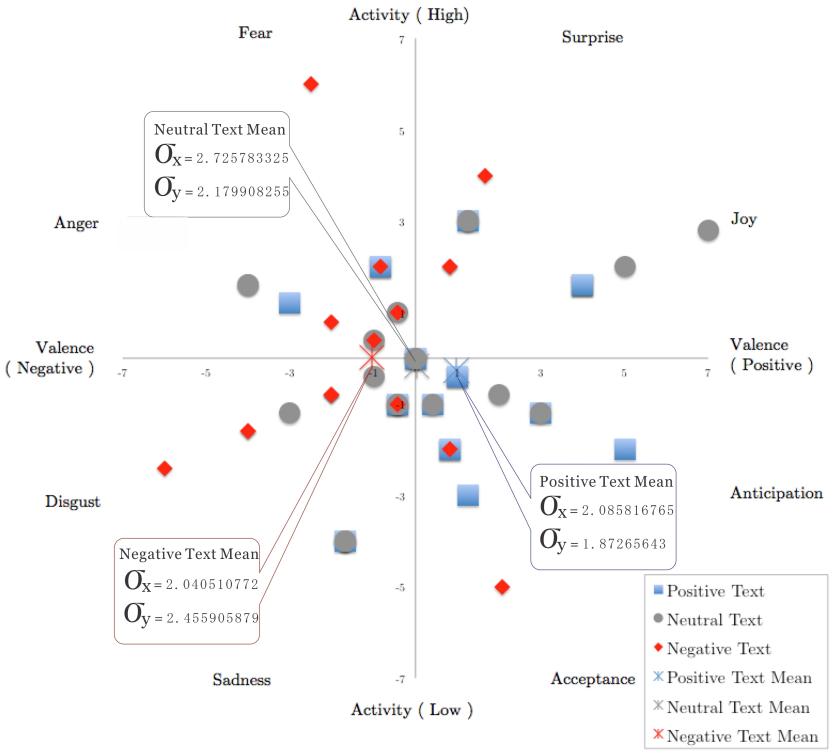

Figure 5.10: Emotional responses in positive touch with negative color stimulus

Figure 5.10 shows the emotional responses in text with positive touch with negative color stimulus for each message category. This graph shows that most

of the responses for positive messages dispersed in various area, mostly either to negative valence area in high activity level, or positive valence area in low activity level, and its mean value are mapped on the positive valence area, in less positive valence and lower activity level, compared to text only stimulus. For neutral message, most of the responses are dispersed into various area, and the mean value for this message is mapped close to the center of the graph. For negative message, most of the responses are still mapped on the negative valence area in slightly lower activity level. The mean value for negative message is mapped in negative valence area with no significant change in activity level compared to text only stimulus.

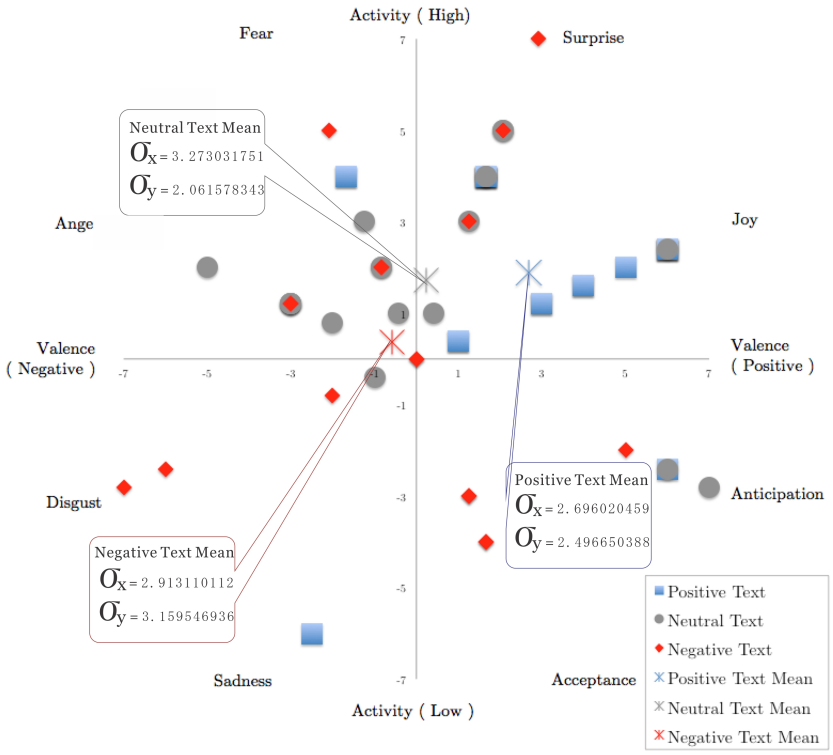

Figure 5.11: Emotional responses in negative touch with positive color stimulus

Figure 5.11 shows the emotional responses in text with negative touch with positive color stimulus for each message category. This graph shows that most of the responses for positive messages and its mean value are mapped on the

positive valence area, in more positive valence and higher activity level, but still less positive valence compared to postive touch with positive color stimulus. For neutral message, most of the responses are dispersed into high activity area, with positive or negative valence. The mean value for this message is mapped in positive valence area with slightly more positive valence, but higher activity level change, compared to the text only stimulus. For negative message, most of the responses are dispersed into high activity area, with positive or negative valence, while its mean value is mapped in negative valence area with slightly high activity level.

Figure 5.12: Emotional responses in negative touch with negative color stimulus

Figure 5.12 shows the emotional responses in text with negative touch with negative color stimulus for each message category. This graph shows that most of the responses for positive messages and its mean value are mapped on the positive valence area, in more positive valence and higher activity level, but still less positive valence compared to postive touch with positive color stimulus. For neutral

message, most of the responses are dispersed into high activity area, with positive or negative valence. The mean value for this message is mapped in positive valence area with near to zero valence, but higher activity level change, compared to the text only stimulus. For negative message, most of the responses are dispersed into negative valence area, with high or low activity level, while its mean value is mapped in negative valence area with more negative valence and not so significant change in activity level.

The changes of the mean values for each category and each stimulus can also be analyzed for a more clear result. Figure 5.13 showed the scattered graph for all the mean values of three categories and their changes to a different stimulus. From this graph, the change of emotional responses to each particular stimulus can be analyzed by zooming into each specific category.

Figure 5.13: Mean of emotional responses of text messages to different stimulus

In the next analysis, p-value testing, introduced by Karl Pearson [24], was used

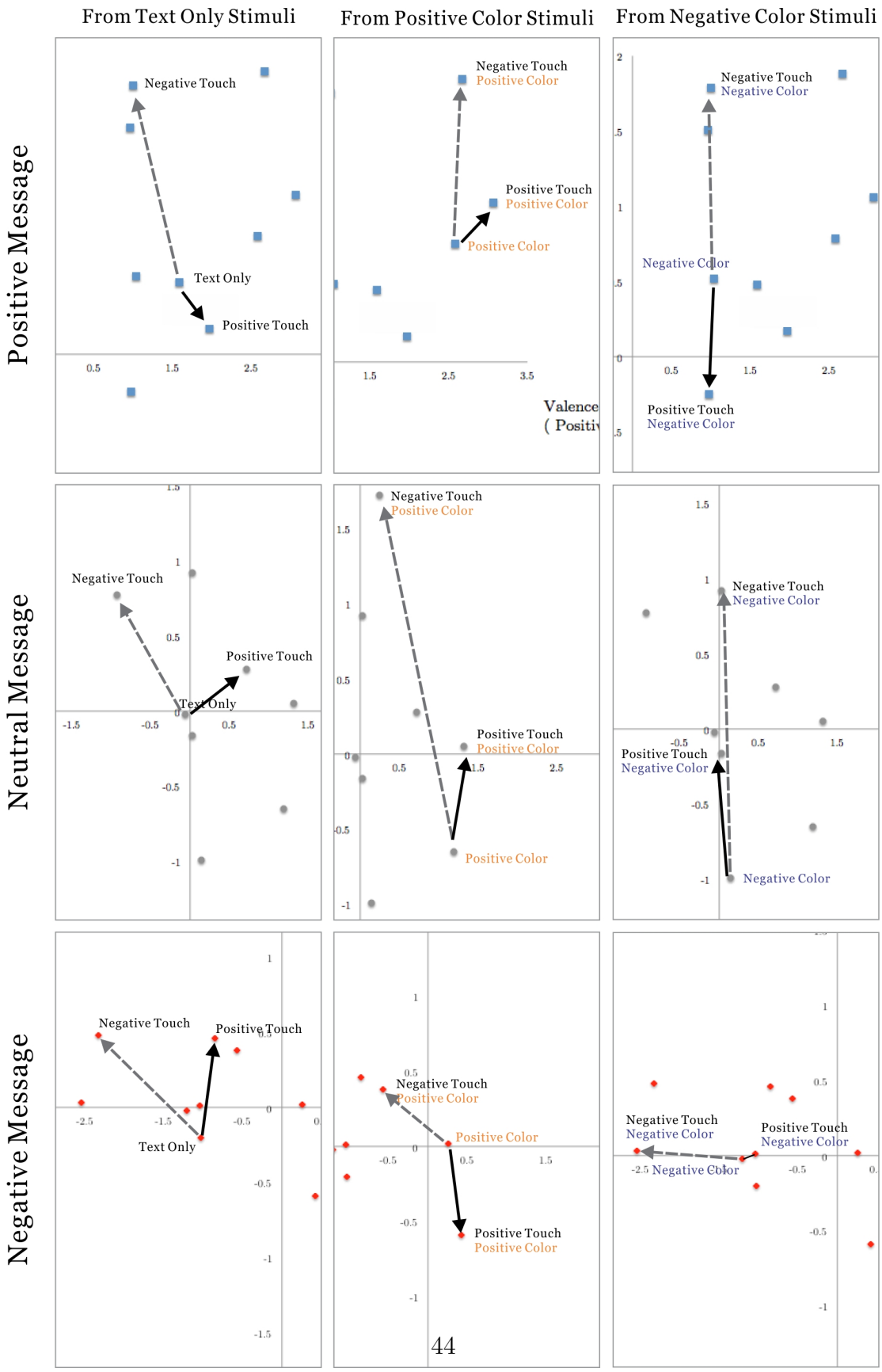

Figure 5.14: Emotional responses change to touch stimulus

as the method for the statistical significance testing, aiming to make sure that the statistic is reliable by calculating the probability of obtaining a test statistic that at least as extreme as the one that was actually observed. When the p-value turns out to be less than a certain significance level, often 0.05 [31], the null hypothesis can be rejected, which indicates that the observed result would be highly unlikely under the null hypothesis and the statistical data is reliable. To calculate the p-value, we can first calculate t-value using the following formula.

$$t = \frac{\overline{x} - \mu_0}{\sigma/\sqrt{n}} \tag{5.1}$$

In the formula above, $\overline{x}$ is the sample mean value, μ_0 is the hypothesized mean value, σ is the standard deviation, and n is the sample size. This value will be calculated separately for valence and activity level, for each different stimuli. Next, the degree of freedom is calculated, which is just one less than the sample size: n-1. Once the t-value and degree of freedom are known, p-value can be calculated from a table or statistical software. In this analysis, p-value was calculated using T-DIST formula in Microsoft Excel.

Figure 5.14 shows the tendency of emotional responses change to touch stimulus. For positive message with positive touch stimuli, the graph shows a that this stimuli can drive the response to a slightly more positive valence, but still can be higher or lower activity level. On the other hand, with negative touch stimuli, the graph shows a consistent result that this stimuli can drive the response to a slightly less positive valence, and significantly higher activity level. For neutral message, positive touch stimuli can drive the response to a slightly higher activity level, in less significant change in the valence when it is combined together with color stimuli. On the other hand, with negative touch stimuli, the graph shows a consistent result that this stimuli can drive the response to a slightly less positive valence, and significantly higher activity level. For negative message, positive touch stimuli can drive the response to a slightly more positive valence, but still can be higher or lower activity level. When it is combined with negative color

stimuli, it does not have significant change both for the activity level and valence. On the other hand, with negative touch stimuli, the graph shows a consistent result that this stimuli can drive the response to a slightly less positive valence, and significantly higher activity level, except for when it is combined with negative color. The effect of touch stimuli has a less significant effect in negative message compared to in the positive and neutral message.

Figure 5.15 shows the tendency of emotional responses change to the stimulus in neutral message. For positive message, with positive color stimuli, the graph shows a consistent result that this stimuli can drive the response to significantly more positive valence and a slightly higher activity level. On the other hand, with negative color stimuli, the graph shows that this stimuli can drive the response to a slightly less positive valence, but still can be higher or lower activity level. For neutral message, with positive color stimuli, the graph shows that this stimuli can drive the response to significantly more positive valence, but still can be higher or lower activity level. On the other hand, with negative color stimuli, the graph shows that this stimuli can drive the response to a slightly higher or lower activity level, with no significant change on the valence. For negative message, with positive color stimuli, the graph shows that this stimuli can drive the response to significantly more positive valence, but still can be higher or lower activity level. On the other hand, with negative color stimuli, the graph shows that this stimuli can drive the response to a slightly less positive valence, but still can be higher or lower activity level in a less significant way. The tendencies shown on Figure 5.14 and Figure 5.15 can be summarized and are shown on Figure 5.16 and Figure 5.17 along with p-value for each stimuli.

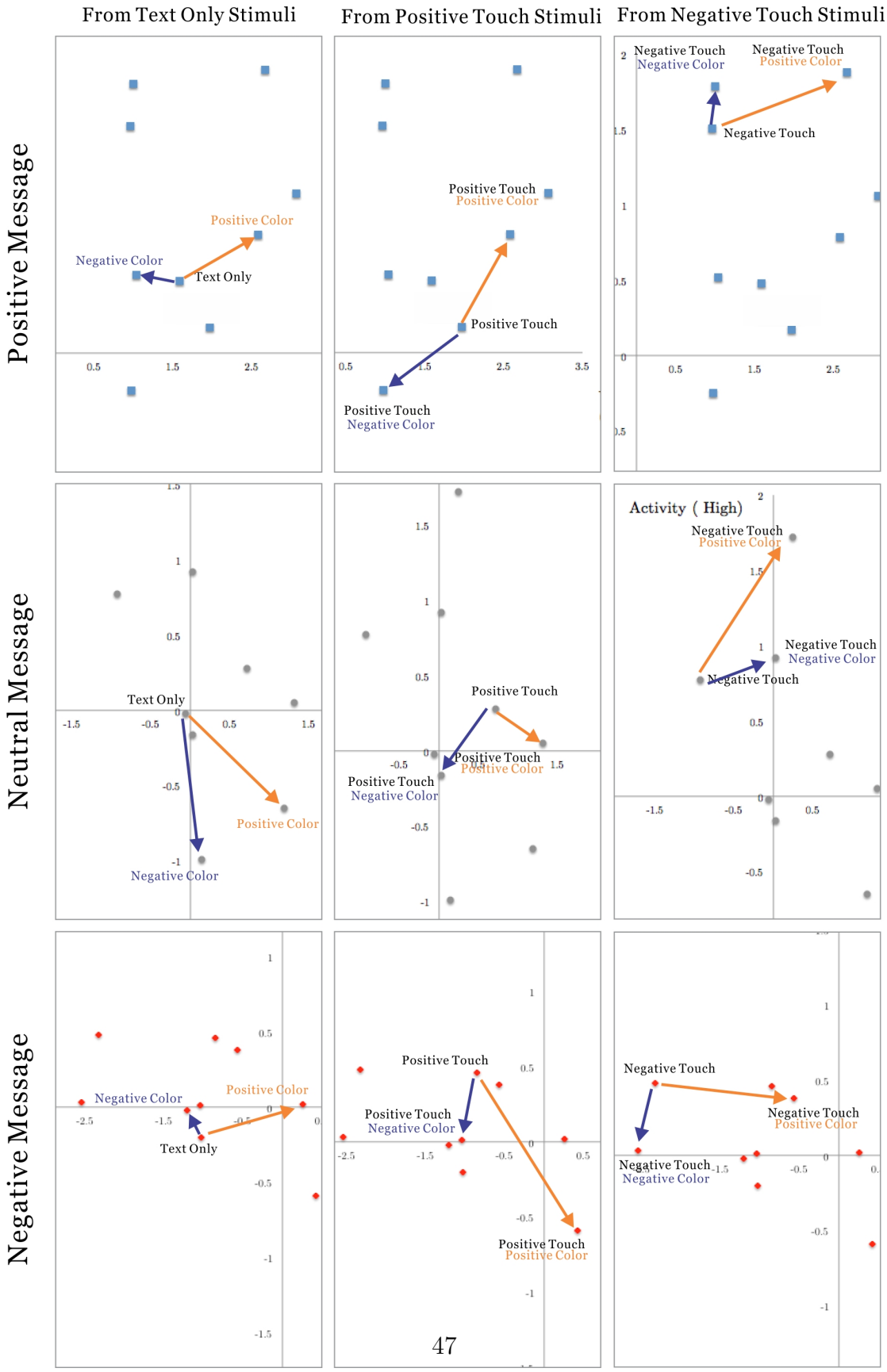

Figure 5.15: Emotional responses change to color stimulus

	Text Only Stimuli			
	Positive Touch		Negative Touch	
	Change to Valence	Change to Activity	Change to Valence	Change to Activity
Positive Message	More Positive	Lower	More Negative	Higher
p-value	0.085484127	0.041589959	0.005940416	0.018879067
Neutral Message	More Positive	Higher	More Negative	Higher
p-value	0.022558282	0.078354818	0.00108509	0.037777055
Negative Message	More Positive	Higher	More Negative	Higher
p-value	0.048686828	0.033527947	0.041056502	0.026123686
	With Positive Color Stimuli			
Positive Message	More Positive	Higher	Almost no change	Higher
p-value	0.038703047	0.009869798	0.007155797	0.010947217
Neutral Message	More Positive	Higher	More Negative	Higher
p-value	0.144547557	0.01686781	0.002000521	0.026599393
Negative Message	More Positive	Lower	More Negative	Higher
p-value	0.040253955	0.00506044	0.004458957	0.002580583
	With Negative Color Stimuli			
Positive Message	Almost no change	Lower	Almost no change	Higher
p-value	0.025358695	0.038293697	0.012684849	0.009392258
Neutral Message	Almost no change	Higher	Almost no change	Higher
p-value	0.006710313	0.021023756	0.000880276	0.015490619
Negative Message	More Positive	Almost no change	More Negative	Almost no change
p-value	0.027721979	0.011925908	0.024219872	0.003274681

Figure 5.16: Emotional responses change to touch stimulus with p-value

	Text Only Stimuli			
	Positive Color		Negative Color	
	Change to Valence	Change to Activity	Change to Valence	Change to Activity
Positive Message	More Positive	Higher	More Negative	Almost no change
p-value	0.044612063	0.107593882	0.030646831	0.083292038
Neutral Message	More Positive	Lower	Almost no change	Lower
p-value	0.15103246	0.047333039	0.089623994	0.061111628
Negative Message	More Positive	Higher	More Negative	Higher
p-value	0.079081783	0.026572705	0.119666356	0.015708449
	With Positive Touch Stimuli			
Positive Message	More Positive	Higher	More Negative	Lower
p-value	0.038703047	0.009869798	0.025358695	0.038293697
Neutral Message	More Positive	Lower	More Negative	Lower
p-value	0.144547557	0.01686781	0.006710313	0.021023756
Negative Message	More Positive	Lower	More Negative	Lower
p-value	0.040253955	0.00506044	0.027721979	0.011925908
	With Negative Touch Stimuli			
Positive Message	More Positive	Higher	Almost no change	Higher
p-value	0.007155797	0.010947217	0.012684849	0.009392258
Neutral Message	More Positive	Higher	More Positive	Higher
p-value	0.002000521	0.026599393	0.000880276	0.015490619
Negative Message	More Positive	Almost no change	More Negative	Almost no change
p-value	0.004458957	0.002580583	0.024219872	0.003274681

Figure 5.17: Emotional responses change to color stimulus with p-value

Table 5.3: Emotional rating of touch experiment 1 result

Duty Cycle	Length (sec)	+	O	-	Value
0%	0	1	14	5	-8
20%	1	8	1	11	-8
40%	1	9	2	9	-1
60%	1	11	1	8	10
80%	1	17	0	3	50
100%	1	9	0	11	-11
20%	2	9	0	11	-3
40%	2	12	0	8	12
60%	2	11	0	9	0
80%	2	12	1	7	17
100%	2	12	0	8	18
20%	3	5	0	15	-35
40%	3	9	0	11	-8
60%	3	9	0	11	-18
80%	3	4	0	16	-48
100%	3	7	0	13	-34
20%	4	4	1	15	-41
40%	4	7	3	10	-5
60%	4	11	0	9	19
80%	4	10	0	10	-9
100%	4	6	0	14	-34
20%	5	5	0	15	-42
40%	5	9	1	10	-2
60%	5	11	1	8	2
80%	5	6	1	13	-17
100%	5	7	0	13	-30

Table 5.4: Patterns for Emotional rating of touch experiment 2

No.	Pattern Name	Duty Cycle	Duration (ms)
1	0	0%	0
2	80% PWM in One Second	80%	100
3	80% PM Four Seconds	80%	400
4	Grin (Quick, Light and Regular Vibration)	60% → 0% → 60% → 0% → 60% → 0% → 60% → 0% → 60%	100 → 100 → 100 → 100 → 100 → 100 → 100 → 100 → 100
5	Cry (Slow Moving Vibration : High, weak,mid, and weak stress)	100% → 20% → 60% → 20%	500 → 700 → 900 → 1100
6	Anger (One strong vibration)	100%	200
7	Surprise (One vibration of thick and mid-stress)	0% → 100% → 20%	3000 → 800 → 200
8	Kiss (Being strong gradually and continuously)	20% → 40% → 60% → 100%	800 → 800 → 800 → 1500
9	Sleepy (Slow and Regular Vibration)	20% → 60% → 20% → 60%	1500 → 1500 → 1500 → 1500

Table 5.5: Emotional rating of touch experiment 2 result

Pattern Name	+	O	-	Value
0	5	14	1	11
80% PWM in One Second	10	1	9	13
80% PM Four Seconds	11	0	9	12
Grin (Quick, Light and Regular Vibration)	18	0	2	56
Cry (Slow Moving Vibration : High, weak,mid, and weak stress)	7	0	13	-33
Anger (One strong vibration)	7	0	13	-28
Surprise (One vibration of thick and mid-stress)	13	0	7	20
Kiss (Being strong gradually and continuously)	12	0	8	27
Sleepy (Slow and Regular Vibration)	9	0	11	-15

Chapter 6
Discussions, Conclusion, and Future Work

6.1. Discussions

In the result shown on Figure 5.4 to 5.12, we can see the dispersion difference of emotional responses from participants for each different condition. In text-only stimulus trials, we can see that almost all responses for positive text message are mapped in positive valence area, almost all responses for neutral text message are mapped around the center of the graph, and almost all responses for negative text message are mapped in the negative valence area.

If we compare the responses for positive touch stimulus, we can see that the results are more dispersed, especially for positive text. By looking at the standard deviation, we can see significant rise in σ_y, meaning that the responses on activity level are really dispersed. Touch stimuli may have resulted different interpretation to participants on the activity level, but did not particularly drive the perception into the opposite direction of negative valence.

The standard deviation value also helped us to recognize how consistent can a stimuli affect emotional perception to a certain category of message under different conditions, for example in Figure 5.7, where positive color stimulus has more consistent effect on neutral text. We can also see similar results in other conditions, where neutral text has comparatively less value of standard deviation. This also proves that emotional perception to neutral text can easily be driven to

the direction of stimuli, compared to positive or negative text. Higher dispersion was shown when the stimuli emotional characteristic is in contradiction with the text message emotion category. In this condition, participants may have a different perception of which direction is stronger for them: the emotion of the text message, or the emotion of stimuli.

In the result shown on Figure 5.14 to 5.17, we can see that the effect of augmentation of both color stimuli and touch stimuli has a different effect depends on which category does the message belong, and what stimuli comes together with it. We can also see that certain stimulus has a consistent effect on driving the emotional response into a certain direction across all different categories of message, while some others may change depends on the message category.

Positive touch stimuli, in most cases, will invoke a slightly higher activity level and slightly more positive emotion, except for when it is used with other negative factor: either negative color, or negative text message itself. On the other hand, negative touch shows the most consistent tendency among other stimulus. Statistical significance analysis has also shown that negative touch stimuli generally has the least p-values in all conditions, meaning that it is the most reliable data. Negative touch stimuli can invoke a higher activity level and slightly more negative emotion, often not so significant. The combination of two contradictory category of emotion in different factors may have resulted the effect difference, compared to when the stimuli is combined with same emotion category, or with neutral emotion. This may be the reason of why touch stimuli is most effective when it was used to accompany neutral message, as it is seen on Figure 5.14.

Positive color stimuli, in most cases, will invoke a slightly higher or lower activity level and more positive emotion. On the other hand, negative color stimuli invokes a lower activity level and slightly more negative emotion, often not so significant. In color stimuli we can also say that the combination of two contradictory category of emotion in different factors may have resulted the effect difference, compared to when the stimuli is combined with same emotion category, or with neutral

emotion. This may be the reason of why color stimuli is also most effective when it was used to accompany neutral message, as it is seen on Figure 5.15. From the p-value analysis, the significance level of most of the responses is less than 0.05, which has statistically proven the reliability of the data.

Based on these findings, we can say that both positive touch and positive color stimuli can invoke a more positive valence. For the positive emotion, the results have shown that positive color stimuli has more effect to convey positive emotion. On the other hand, both negative touch and negative color stimuli can invoke a more negative valence, in a less significant way compared to the positive stimulus. In fact, another finding that we got from this result is, touch stimulus has more effect on the activity level, especially for the negative touch stimuli, which has most tendency compared to other stimulus, to invoke a higher activity level and slightly more negative valence.

With current sample of data, it is still hard to conclude the exact trend or consistency of each condition, but we can still see it clearly for dominant result, for instance in negative touch stimuli. Conducting the research with a bigger sample size, for example 100 or 1000, will allow us to collect more evidence and discover more contrast result for each condition tested.

These findings can be implemented into the CMC environment, to support the assessment of emotional state. For example, to invoke a higher activity emotional level and more positive emotional valency, we can use positive color stimuli, combined with negative touch stimuli, as a hybrid approach that is proposed in RingU system. At first, this may sound contradictory, but sometimes combining two elements in opposite characteristic may bring out a more effective result. In real life, we can see another example when some people try to put salt into watermelon to bring out the natural sweetness from the watermelon.

As a contribution for the future application, this thesis has proven the idea that non-verbal stimuli can change the emotional perception to a verbal cue, and it can be driven into the direction of the emotional characteristic of the

stimuli. By implementing these findings into a real life application, the author hopes that it can help a better emotional state assessment in computer mediated communication. Sender can augment non-verbal cues to strengthen their verbal message and receiver can feel more by receiveing more than just a message. This may impact to the society as a new method to support in putting more emotional information in Computer Mediated Communication as it is possible in real life face-to-face communication.

6.2. Conclusion and Future Work

6.2.1 Conclusion

In this thesis, Ring U, a ring-shaped wearable system aimed at promoting emotional communications in remote communication between people using the vibro-tactile and color lighting expressions is proposed as a hybrid approach in attempt to place a greater emphasis on existing cues by developing a new strategy in CMC environment.

A scientific study was conducted in two parts: A Pre-Evaluation Experiment to 20 participants, and a main experiment to 20 participants. The author explored the emotional augmentation benefit of vibro-tactile, color lighting, and simultaneous transmission of both signals to accompany text messages. The aim is to study the relationship and the benefit of utilizing both verbal and non-verbal channel on emotional response in Computer Mediated Communication. From the experiment, we can conclude that both positive touch and positive color stimuli can invoke a more positive valence, especially in positive color stimuli, where it has more effect to convey positive emotion. On the other hand, both negative touch and negative color stimuli can invoke a more negative valence, as it is expected in the hypothesis. Another findings from the experiment is that compared to the effect on valence, touch stimulus has more effect on the activity level, especially

for the negative touch stimuli, which has most tendency compared to other stimulus, to invoke a higher activity level and slightly more negative valence. This has proven that touch and color stimuli is effective to invoke and change the emotional perception to a text message.

6.2.2 Future Work

There are still a lot of improvement needed in the RingU system. In the implementation part, we still need to make the hardware even more compact that it actually fits in the size of a ring. Hardware limitations like size limitation and connectivity limitation still exist on the implementation part of this thesis. By implementing the system into a real compact ring, we may get a more interesting and more suitable result, especially for the user evaluation of the system.

For the scientific study part, emotional response is still a subjective and may need a deeper research to conclude the best result. By adding more combinations to the stimuli, for example to include more colors and more patterns to the main experiment, we may have a more interesting and result, even if we test it for the same emotional category. Other suggested methods for measuring emotion can also be considered to be used in this scientific study to explore more undiscovered findings. More extensive research in this topic is still needed to discover about more detailed augmentation method of the non-verbal stimulus, and how it may result differently. By conducting the study with more extensive patterns of stimuli, bigger sample number, and different emotional measurements, one possible application that can be developed based on the findings with stronger evidence is emoticons for vibro-tactile and color patterns that represents different types of emotions and can be used in various systems.

Acknowledgements

Al-hamdu lillahi rabbil 'alamin. All the praises and thanks be to Allah, the Almighty, that only by His willing I was able to finish writing this thesis.

I would like to express my gratitude to Prof. Adrian David Cheok for the support and guidance during my study in Keio Media Design. Without the kind support and help from him, it would not have been possible to conduct my research and to finish this thesis. I would like to also show my gratitude to Prof. Masa Inakage, Prof. Masahiko Inami, and Prof. Ichiya Nakamura for being really supportive supervisors during the process of this thesis writing and the completion of my master course. I would also like to thank fellow laboratory members, professors, and friends who had helped me all along on this research.

Finally, a very special thanks to my mom Andam Dewi, my dad Bambang Budiono, my brother Faris Rizky Andika and my sister Alyssa Shafa Andiana for the endless love and for keep encouraging me that I can finally finish my master study in Keio University.

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Appendix

A. RingU Prototype Arduino Sketch

```
int buttonPin = 2;
int buttonState = 0;
int val;

int redPin = 11;
int bluePin = 12;
int greenPin = 13;
int vibPin = 9;


void setup() {

  Serial.begin(9600);
  pinMode(buttonPin, INPUT);
  pinMode(redPin, OUTPUT);
  pinMode(bluePin, OUTPUT);
  pinMode(greenPin, OUTPUT);
  pinMode(vibPin, OUTPUT);

}

void loop(){
  buttonState = digitalRead(buttonPin);
  if (buttonState == LOW) {
    Serial.print('E');
    digitalWrite(redPin, HIGH);
```

```
27    }
28    if (buttonState == HIGH) {
29      Serial.print('N');
30      digitalWrite(redPin, LOW);
31    }
32    if (Serial.available()) {
33      val = Serial.read();
34      if (val == 'E') {
35            digitalWrite(redPin, HIGH);
36            digitalWrite(bluePin, HIGH);
37            digitalWrite(greenPin, HIGH);
38            digitalWrite(vibPin, HIGH);
39      }
40      if (val == 'N'){
41            digitalWrite(greenPin, LOW);
42            digitalWrite(redPin, LOW);
43            digitalWrite(bluePin, LOW);
44            digitalWrite(vibPin, LOW);
45      }
46    }
47  }
```

B. Emotion Rating Web Application (JavaScript)

```
1   $(document).ready(function() {
2           // Breakout JS Code //
3           var IOBoard = BO.IOBoard;
4           var IOBoardEvent = BO.IOBoardEvent;
5           var LED = BO.io.LED;
6           var RGBLED = BO.io.RGBLED;
7           var host = window.location.hostname;
8       var Oscillator = BO.generators.Oscillator;
9           if (window.location.protocol.indexOf("file:") === 0) host = "131.113.137.242";
10          var arduino = new IOBoard(host, 8887);
```

```
11
12          // Arduino Components Declaration
13          var motor;
14          var motorPin = 9;
15          var redPin = 3;
16          var greenPin = 5;
17          var bluePin = 6;
18          var vibrationIndex = -1;
19          var currentVibration = -1;
20
21          var currentText;
22
23          //Previously selected texts declaration
24          var tp = "Yay, Finally! lol. I missed our cinema trip last week";
25          var t0 = "At home by the way";
26          var tn = "No, but you told me, before you got drunk!";
27
28          //Vibration times (In Sec)
29          var SHORT = 1;
30          var MIDDLE_SHORT = 2;
31          var MIDDLE = 3;
32          var MIDDLE_LONG = 4;
33          var LONG = 5;
34
35          //Vibration stength
36          var SMALL = 0.2;
37          var MEDIUM_SMALL = 0.4;
38          var MEDIUM = 0.6;
39          var MEDIUM_LARGE = 0.8;
40          var LARGE = 1.0
41
42          var vibrationSequence =
                [0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26];
43          arduino.addEventListener(IOBoardEvent.READY, onReady); // indicates IOBoard
                is ready to send/recieve
44
```

```
45          // Initialization for PubNub Server
46      var pubnub = PUBNUB.init({
47          publish_key : 'pub-c-bad6e5cb-bfb4-4b16-b92f-2bb76c9606d1',
48          subscribe_key : 'sub-c-16ed5480-4c78-11e3-982a-02ee2ddab7fe'
49      })
50
51      // LISTEN to a channel in PubNub Server
52      pubnub.subscribe({
53          channel : "gilworld",
54          message : function(m){ },
55          connect : publish
56      })
57
58      // SEND to a channel in Pubnub Server
59      function publish() {
60
61      }
62
63          //Function for randomizing the order of vibrations
64          function fisherYatesShuffle () {
65                  for (var i=26; i > 0; i--) {
66                          var j = Math.floor((Math.random()*i));
67                          var buffer = vibrationSequence[j];
68                          vibrationSequence[j] = vibrationSequence[i];
69                          vibrationSequence[i] = buffer;
70                  }
71          }
72
73          function getRandomInt (min, max) {
74      return Math.floor(Math.random() * (max - min + 1)) + min;
75          }
76
77          function printList () {
78                  var duration;
79                  var strength;
80                  console.log ("Vibration # Duration Strength");
```

```
81              console.log ("---------- -------- --------");
82              for (var i=0; i<=26; i++) {
83                      var index = vibrationSequence[i];
84
85                      console.log (i + " ");
86              }
87      }
88
89      function onReady(event) {
90              arduino.removeEventListener(IOBoardEvent.READY, onReady);
91              motor = new LED(arduino, arduino.getDigitalPin(motorPin));
92              light = new RGBLED(arduino, arduino.getDigitalPin(redPin), arduino.
                    getDigitalPin(greenPin), arduino.getDigitalPin(bluePin),RGBLED.
                    COMMON_CATHODE);
93
94
95
96              fisherYatesShuffle ();
97              printList();
98              turnOffLight();
99      }
100
101     function activateMotor () {
102
103
104             vibrationIndex++;
105             if (vibrationIndex > 26) return; //Just ended
106             currentVibration = vibrationSequence [vibrationIndex]; //Get the
                    ranndomized vibration at the index
107
108             //Defining each combinations
109
110             switch (currentVibration) {
111                             case 0:
112
113                                     turnOffLight();
```

```
114
115                     //no motor
116
117                     currentText = tp;
118                     console.log ("now we are vibrating on set 0 "
                            + tp);
119                     break;
120             case 1:
121
122                     turnOffLight();
123
124                     //no motor
125
126                     currentText = t0;
127                     console.log ("now we are vibrating on set 1 "
                            + t0);
128
129                     break;
130             case 2:
131
132                     turnOffLight();
133
134                     //no motor
135
136                     currentText = tn;
137                     console.log ("now we are vibrating on set 2 "
                            + tn);
138
139                     break;
140             case 3:
141
142                     turnOffLight();
143
144                     motor.on();
145                     motor.intensity = MEDIUM;
146                     setTimeout (turnOffMotor, 100);
```

```
147                     setTimeout (setMotorMedium, 200);
148                     setTimeout (turnOffMotor, 300);
149                     setTimeout (setMotorMedium, 400);
150                     setTimeout (turnOffMotor, 500);
151                     setTimeout (setMotorMedium, 600);
152                     setTimeout (turnOffMotor, 700);
153                     setTimeout (setMotorMedium, 800);
154                     setTimeout (turnOffMotor, 900);
155                     setTimeout (setMotorMedium, 1000);
156                     setTimeout (turnOffMotor, 1100);
157
158                     currentText = tp;
159                     console.log ("now we are vibrating on set 3 ,
                            touch + " + tp);
160                     break;
161             case 4:
162
163                     turnOffLight();
164
165                     motor.on();
166                     motor.intensity = MEDIUM;
167                     setTimeout (turnOffMotor, 100);
168                     setTimeout (setMotorMedium, 200);
169                     setTimeout (turnOffMotor, 300);
170                     setTimeout (setMotorMedium, 400);
171                     setTimeout (turnOffMotor, 500);
172                     setTimeout (setMotorMedium, 600);
173                     setTimeout (turnOffMotor, 700);
174                     setTimeout (setMotorMedium, 800);
175                     setTimeout (turnOffMotor, 900);
176                     setTimeout (setMotorMedium, 1000);
177                     setTimeout (turnOffMotor, 1100);
178
179                     currentText = t0;
180                     console.log ("now we are vibrating on set 4 ,
                            touch + " + t0);
```

```
181
182                     break;
183             case 5:
184
185                     turnOffLight();
186
187                     motor.on();
188                     motor.intensity = MEDIUM;
189                     setTimeout (turnOffMotor, 100);
190                     setTimeout (setMotorMedium, 200);
191                     setTimeout (turnOffMotor, 300);
192                     setTimeout (setMotorMedium, 400);
193                     setTimeout (turnOffMotor, 500);
194                     setTimeout (setMotorMedium, 600);
195                     setTimeout (turnOffMotor, 700);
196                     setTimeout (setMotorMedium, 800);
197                     setTimeout (turnOffMotor, 900);
198                     setTimeout (setMotorMedium, 1000);
199                     setTimeout (turnOffMotor, 1100);
200
201                     currentText = tn;
202                     console.log ("now we are vibrating on set 5 ,
                            touch + " + tn);
203
204                     break;
205             case 6:
206
207                     turnOffLight();
208
209                     motor.on();
210                     motor.intensity = LARGE;
211                     setTimeout (turnOffMotor, 500);
212                     setTimeout (setMotorSmall, 550);
213                     setTimeout (setMotorMediumLarge, 1250);
214                     setTimeout (turnOffMotor, 2150);
215                     setTimeout (setMotorSmall, 2200);
```

```
216                 setTimeout (turnOffMotor, 3300);
217
218                 currentText = tp;
219                 console.log ("now we are vibrating on set 6 ,
                        touch - " + tp);
220                 break;
221             case 7:
222
223                 turnOffLight();
224
225                 motor.on();
226                 motor.intensity = LARGE;
227                 setTimeout (turnOffMotor, 500);
228                 setTimeout (setMotorSmall, 550);
229                 setTimeout (setMotorMediumLarge, 1250);
230                 setTimeout (turnOffMotor, 2150);
231                 setTimeout (setMotorSmall, 2200);
232                 setTimeout (turnOffMotor, 3300);
233
234                 currentText = t0;
235                 console.log ("now we are vibrating on set 7 ,
                        touch - " + t0);
236
237                 break;
238             case 8:
239
240                 turnOffLight();
241
242                 motor.on();
243                 motor.intensity = LARGE;
244                 setTimeout (turnOffMotor, 500);
245                 setTimeout (setMotorSmall, 550);
246                 setTimeout (setMotorMediumLarge, 1250);
247                 setTimeout (turnOffMotor, 2150);
248                 setTimeout (setMotorSmall, 2200);
249                 setTimeout (turnOffMotor, 3300);
```

```
250
251                 currentText = tn;
252                 console.log ("now we are vibrating on set 8 ,
                        touch - " + tn);
253
254                 break;
255             case 9:
256
257                 light.fadeTo(255,153,0);
258
259                 //no motor
260
261                 currentText = tp;
262                 console.log ("now we are vibrating on set 9,
                        color + " + tp);
263                 break;
264             case 10:
265
266                 light.fadeTo(255,153,0);
267
268                 //no motor
269
270                 currentText = t0;
271                 console.log ("now we are vibrating on set 10,
                        color + " + t0);
272
273                 break;
274             case 11:
275
276                 light.fadeTo(255,153,0);
277
278                 //no motor
279
280                 currentText = tn;
281                 console.log ("now we are vibrating on set 11,
                        color + " + tn);
```

```
282
283                     break;
284             case 12:
285
286                     light.fadeTo(0,0,255);
287
288                     //no motor
289
290                     currentText = tp;
291                     console.log ("now we are vibrating on set 12,
                            color - " + tp);
292                     break;
293             case 13:
294
295                     light.fadeTo(0,0,255);
296
297                     //no motor
298
299                     currentText = t0;
300                     console.log ("now we are vibrating on set 13,
                            color - " + t0);
301
302                     break;
303             case 14:
304
305                     light.fadeTo(0,0,255);
306
307                     //no motor
308
309                     currentText = tn;
310                     console.log ("now we are vibrating on set 14,
                            color - " + tn);
311
312                     break;
313             case 15:
314
```

```
315                     light.fadeTo(255,153,0);
316
317                     motor.on();
318                     motor.intensity = MEDIUM;
319                     setTimeout (turnOffMotor, 100);
320                     setTimeout (setMotorMedium, 200);
321                     setTimeout (turnOffMotor, 300);
322                     setTimeout (setMotorMedium, 400);
323                     setTimeout (turnOffMotor, 500);
324                     setTimeout (setMotorMedium, 600);
325                     setTimeout (turnOffMotor, 700);
326                     setTimeout (setMotorMedium, 800);
327                     setTimeout (turnOffMotor, 900);
328                     setTimeout (setMotorMedium, 1000);
329                     setTimeout (turnOffMotor, 1100);
330
331                     currentText = tp;
332                     console.log ("now we are vibrating on set 15 ,
                            touch + color + " + tp);
333                     break;
334             case 16:
335
336                     light.fadeTo(255,153,0);
337
338                     motor.on();
339                     motor.intensity = MEDIUM;
340                     setTimeout (turnOffMotor, 100);
341                     setTimeout (setMotorMedium, 200);
342                     setTimeout (turnOffMotor, 300);
343                     setTimeout (setMotorMedium, 400);
344                     setTimeout (turnOffMotor, 500);
345                     setTimeout (setMotorMedium, 600);
346                     setTimeout (turnOffMotor, 700);
347                     setTimeout (setMotorMedium, 800);
348                     setTimeout (turnOffMotor, 900);
349                     setTimeout (setMotorMedium, 1000);
```

```
350                 setTimeout (turnOffMotor, 1100);
351
352                 currentText = t0;
353                 console.log ("now we are vibrating on set 16 ,
                        touch + color + " + t0);
354
355                 break;
356             case 17:
357
358                 light.fadeTo(255,153,0);
359
360                 motor.on();
361                 motor.intensity = MEDIUM;
362                 setTimeout (turnOffMotor, 100);
363                 setTimeout (setMotorMedium, 200);
364                 setTimeout (turnOffMotor, 300);
365                 setTimeout (setMotorMedium, 400);
366                 setTimeout (turnOffMotor, 500);
367                 setTimeout (setMotorMedium, 600);
368                 setTimeout (turnOffMotor, 700);
369                 setTimeout (setMotorMedium, 800);
370                 setTimeout (turnOffMotor, 900);
371                 setTimeout (setMotorMedium, 1000);
372                 setTimeout (turnOffMotor, 1100);
373
374                 currentText = tn;
375                 console.log ("now we are vibrating on set 17 ,
                        touch + color + " + tn);
376
377                 break;
378             case 18:
379
380                 light.fadeTo(0,0,255);
381
382                 motor.on();
383                 motor.intensity = MEDIUM;
```

```
384                 setTimeout (turnOffMotor, 100);
385                 setTimeout (setMotorMedium, 200);
386                 setTimeout (turnOffMotor, 300);
387                 setTimeout (setMotorMedium, 400);
388                 setTimeout (turnOffMotor, 500);
389                 setTimeout (setMotorMedium, 600);
390                 setTimeout (turnOffMotor, 700);
391                 setTimeout (setMotorMedium, 800);
392                 setTimeout (turnOffMotor, 900);
393                 setTimeout (setMotorMedium, 1000);
394                 setTimeout (turnOffMotor, 1100);
395
396                 currentText = tp;
397                 console.log ("now we are vibrating on set 18 ,
                        touch + color - " + tp);
398                 break;
399             case 19:
400
401                 light.fadeTo(0,0,255);
402
403                 motor.on();
404                 motor.intensity = MEDIUM;
405                 setTimeout (turnOffMotor, 100);
406                 setTimeout (setMotorMedium, 200);
407                 setTimeout (turnOffMotor, 300);
408                 setTimeout (setMotorMedium, 400);
409                 setTimeout (turnOffMotor, 500);
410                 setTimeout (setMotorMedium, 600);
411                 setTimeout (turnOffMotor, 700);
412                 setTimeout (setMotorMedium, 800);
413                 setTimeout (turnOffMotor, 900);
414                 setTimeout (setMotorMedium, 1000);
415                 setTimeout (turnOffMotor, 1100);
416
417                 currentText = t0;
```

```
418                 console.log ("now we are vibrating on set 19 ,
                        touch + color - " + t0);
419
420                 break;
421             case 20:
422
423                 light.fadeTo(0,0,255);
424
425                 motor.on();
426                 motor.intensity = MEDIUM;
427                 setTimeout (turnOffMotor, 100);
428                 setTimeout (setMotorMedium, 200);
429                 setTimeout (turnOffMotor, 300);
430                 setTimeout (setMotorMedium, 400);
431                 setTimeout (turnOffMotor, 500);
432                 setTimeout (setMotorMedium, 600);
433                 setTimeout (turnOffMotor, 700);
434                 setTimeout (setMotorMedium, 800);
435                 setTimeout (turnOffMotor, 900);
436                 setTimeout (setMotorMedium, 1000);
437                 setTimeout (turnOffMotor, 1100);
438
439                 currentText = tn;
440                 console.log ("now we are vibrating on set 20 ,
                        touch + color - " + tn);
441
442                 break;
443             case 21:
444
445                 light.fadeTo(255,153,0);
446
447                 motor.on();
448                 motor.intensity = LARGE;
449                 setTimeout (turnOffMotor, 500);
450                 setTimeout (setMotorSmall, 550);
451                 setTimeout (setMotorMediumLarge, 1250);
```

```
452                     setTimeout (turnOffMotor, 2150);
453                     setTimeout (setMotorSmall, 2200);
454                     setTimeout (turnOffMotor, 3300);
455
456                     currentText = tp;
457                     console.log ("now we are vibrating on set 21 ,
                            touch - color + " + tp);
458                     break;
459                 case 22:
460
461                     light.fadeTo(255,153,0);
462
463                     motor.on();
464                     motor.intensity = LARGE;
465                     setTimeout (turnOffMotor, 500);
466                     setTimeout (setMotorSmall, 550);
467                     setTimeout (setMotorMediumLarge, 1250);
468                     setTimeout (turnOffMotor, 2150);
469                     setTimeout (setMotorSmall, 2200);
470                     setTimeout (turnOffMotor, 3300);
471
472                     currentText = t0;
473                     console.log ("now we are vibrating on set 22 ,
                            touch - color + " + t0);
474
475                     break;
476                 case 23:
477
478                     light.fadeTo(255,153,0);
479
480                     motor.on();
481                     motor.intensity = LARGE;
482                     setTimeout (turnOffMotor, 500);
483                     setTimeout (setMotorSmall, 550);
484                     setTimeout (setMotorMediumLarge, 1250);
485                     setTimeout (turnOffMotor, 2150);
```

```
486                 setTimeout (setMotorSmall, 2200);
487                 setTimeout (turnOffMotor, 3300);
488
489                 currentText = tn;
490                 console.log ("now we are vibrating on set 23 ,
                        touch - color + " + tn);
491
492                 break;
493             case 24:
494
495                 light.fadeTo(0,0,255);
496
497                 motor.on();
498                 motor.intensity = LARGE;
499                 setTimeout (turnOffMotor, 500);
500                 setTimeout (setMotorSmall, 550);
501                 setTimeout (setMotorMediumLarge, 1250);
502                 setTimeout (turnOffMotor, 2150);
503                 setTimeout (setMotorSmall, 2200);
504                 setTimeout (turnOffMotor, 3300);
505
506                 currentText = tp;
507                 console.log ("now we are vibrating on set 24 ,
                        touch - color - " + tp);
508                 break;
509             case 25:
510
511                 light.fadeTo(0,0,255);
512
513                 motor.on();
514                 motor.intensity = LARGE;
515                 setTimeout (turnOffMotor, 500);
516                 setTimeout (setMotorSmall, 550);
517                 setTimeout (setMotorMediumLarge, 1250);
518                 setTimeout (turnOffMotor, 2150);
519                 setTimeout (setMotorSmall, 2200);
```

```
520                                     setTimeout (turnOffMotor, 3300);
521
522                                     currentText = t0;
523                                     console.log ("now we are vibrating on set 25 ,
                                            touch - color - " + t0);
524
525                                     break;
526                             case 26:
527
528                                     light.fadeTo(0,0,255);
529
530                                     motor.on();
531                                     motor.intensity = LARGE;
532                                     setTimeout (turnOffMotor, 500);
533                                     setTimeout (setMotorSmall, 550);
534                                     setTimeout (setMotorMediumLarge, 1250);
535                                     setTimeout (turnOffMotor, 2150);
536                                     setTimeout (setMotorSmall, 2200);
537                                     setTimeout (turnOffMotor, 3300);
538
539                                     currentText = tn;
540                                     console.log ("now we are vibrating on set 26 ,
                                            touch - color - " + tn);
541
542                                     break;
543
544                             default:
545                                     duration = " ZERO DURATION, ";
546                         }
547
548
549             $("#message").text(currentText);
550             pubnub.publish({
551         channel : "gilworld",
552         message : currentText
553     });
```

```
554
555
556 }
557         function turnOffMotor () {
558
559                 motor.off()
560
561
562         }
563
564         function turnOffLight (){
565                 light.fadeOut(50);
566         }
567
568                 function setMotorSmall (){
569                 motor.off();
570                 motor.intensity = SMALL;
571                 motor.on();
572                 motor.intensity = SMALL;
573
574         }
575         function setMotorMediumSmall (){
576                 motor.off();
577                 motor.intensity = MEDIUM_SMALL;
578                 motor.on();
579                 motor.intensity = MEDIUM_SMALL;
580
581         }
582         function setMotorMedium (){
583                 motor.off();
584                 motor.intensity = MEDIUM;
585                 motor.on();
586                 motor.intensity = MEDIUM;
587
588         }
589         function setMotorMediumLarge (){
```

```
590             motor.off();
591             motor.intensity = MEDIUM_LARGE;
592             motor.on();
593             motor.intensity = MEDIUM_LARGE;
594
595
596         }
597         function setMotorLarge (){
598             motor.off();
599             motor.intensity = LARGE;
600             motor.on();
601             motor.intensity = LARGE;
602
603
604         }
605         function setMotorGiant (){
606             motor.off();
607             motor.intensity = 1;
608             motor.on();
609             motor.intensity = 1;
610
611
612         }
613
614
615         //----------------------Parse Code
                ----------------------//
616         var currentOID;
617         var instructions = "You will feel vibration touch from the ring. Rate the
              emotional feel of the vibration by clicking on the emotion wheel.\n\nSelect
              what you think the predominant emotion is from one of:"
618               + " surprise, joy, anticipation, acceptance, sadness, disgust, anger and
                    fear. Rate the strength of the emotion from weak (1) to strong (7)
                    by clicking the corresponding circle in the emotion wheel.\n\
                    nHowever, if you think the vibration is emotionally neutral"
```

```
619             + " then click the neutral circle at the centre of the wheel.\n\nWhen
                    you have emotionally rated the vibration click the next button at the
                     bottom of the screen."
620             + "\n\nYou will be shown 10 text messages that we would like you to
                    emotionally rate."
621             + "\n\nWhen you are ready click the OK button below.";
622         bootbox.alert(instructions, function() {
623             bootbox.prompt("Hi! Thanks for helping us. What is your name?",
                    function(result) {
624                     activateMotor ();
625                     if (result == null) {
626
627                     } else {
628
629                             $("#name").text(result)
630                     }
631             });
632         });
633
634         var qCounter = 0;
635         var Message = Parse.Object.extend("Color");
636         var query = new Parse.Query(Message);
637         query.ascending("textId");
638
639         //////////querying for questionS
640         query.find({
641             success: function(results) {
642                     // Successfully retrieved the object.
643                     console.dir(results);
644
645                     currentOID = results[qCounter].id;
646                     qCounter++;
647             }, error: function(error) {
648                     alert("Error: " + error.code + " " + error.message);
649             }
650         });
```

```
651
652
653         /////////querying end
654
655         var isDone = 0;
656
657         $("#emotionform").on("submit", function(e) {
658                 e.preventDefault();
659                 var validate= false;
660                 if($('input[name=radio-2-set]:checked', '#emotionform').val()!=null){
                        validate = true;}
661
662                 if(!validate){
663                         bootbox.alert("Please select your emotion before proceeding",
                                function() {});
664                         return false;
665                 }
666                 else {
667                         console.log("To report: " + qCounter);
668                         //ok, disable the form while submitting and show a loading gfx
669                         $(this).attr("disabled","disabled");
670
671                         if(isDone==1) {
672                                 bootbox.alert("Thanks a lot for helping! :)", function()
                                        {
673                                             //Example.show("Hello world callback");
674                                             window.location.href = "http://mixedrealitylab
                                                    .org";
675                                 });
676                         }
677
678
679
680                         /////// Save data to database
681                         var Emotions = Parse.Object.extend("MainEmotions");
682                         var emotion = new Emotions();
```

```
683                         emotion.set("messageNum", qCounter);
684                         emotion.set("name", $("#name").text());
685                         emotion.set("emotionScore", $('input[name=radio-2-set]:
                                checked', '#emotionform').val());
686                         emotion.set("vibrationID", currentVibration);
687
688
689                         emotion.save(null, {success: function(emotion) {}, error:
                                function(emotion, error) {}});
690                 }
691                 ///////////////querying for questions
692                 query.find({
693                         success: function(results) {
694                                 // Successfully retrieved the object.
695                                 console.dir(results);
696                                 currentOID = results[qCounter].id;
697                                 qCounter++;
698                                 activateMotor();
699
700
701                                 if(qCounter==results.length) {
702                                         $("#nextbtn").text("Finish");
703                                         isDone = 1;
704                                 }
705                         }, error: function(error) {alert("Error: " + error.code + " " +
                                error.message);}
706                 });
707                 ////////////////////querying end
708                 $('#emotionform').find("textarea,:text,select").val("").end().find(":
                        checked").prop("checked",false);
709         });
710 });
```

C. Text Messages List with Emotional Responses

No	Message	+	O	-	Value
1	I'm going to try for 2 months ha ha only joking	15	0	5	32
2	I'll leave around four, ok?	17	2	1	58
3	Been running but only managed 5 minutes and then needed oxygen! Might have to resort to the roller option!	16	1	3	49
4	Are you available for soiree on June 3rd?	17	2	1	70
5	Hm good morning, headache anyone? :-)	16	0	4	39
6	Oops sorry. Just to check that you don't mind picking me up tomo at half eight from station. Would that be ok?	12	2	6	37
7	Oops. 4 got that bit.	1	0	19	-43
8	Ah, well that confuses things, doesn't it?	11	0	9	2
9	Aah bless! How's your arm?	13	2	5	22
10	Err... Cud do. I'm going to at 8pm. I haven't got a way to contact him until then.	2	1	17	-43
11	Erm. I thought the contract ran out the4th of october.	8	1	11	-14
12	Did you show him and wot did he say or could u not c him 4 dust?	3	1	16	-41
13	They can try! They can get lost, in fact. Tee hee	14	1	5	24
14	I think your mentor is , but not 100 percent sure.	7	3	10	-1
15	I just cooked a rather nice salmon a la you	19	1	0	74
16	She's borderline but yeah whatever.	18	1	1	56
17	did u get that message	7	6	7	7
18	Thnx dude. u guys out 2nite?	16	3	1	49
19	Thank you. And by the way, I just lost.	3	1	16	-41
20	Good stuff, will do.	20	0	0	77

21	I like to think there's always the possibility of being in a pub later.	10	6	4	22
22	What time. I'm out until prob 3 or so	15	2	3	46
23	R u in this continent?	14	5	1	45
24	Nope thats fine. I might have a nap tho!	11	2	7	21
25	No, but you told me you were going, before you got drunk!	1	0	19	-62
26	No. Yes please. Been swimming?	10	5	5	12
27	Hmm well, night night	7	2	11	-4
28	Hmm ok, i'll stay for like an hour cos my eye is really sore!	6	3	11	-12
29	Annoying isn't it.	6	0	14	-47
30	;-(oh well, c u later	17	2	1	70
31	Yes i thought so. Thanks.	15	2	3	43
32	Yeah do! Don't stand to close tho- you'll catch something!	15	5	0	53
33	Yeah whatever lol	14	3	3	50
34	Yes i will be there. Glad you made it.	18	2	0	63
35	Yeah work is fine, started last week, all the same stuff as before, dull but easy and guys are fun!	18	2	0	60
36	Yes. Last practice	9	7	4	13
37	Yes fine	12	5	3	37
38	Yeah no probs - last night is obviously catching up with you... Speak soon	13	4	3	42
39	yay! finally lol. i missed our cinema trip last week :-(	20	0	0	96
40	Boo. How's things? I'm back at home and a little bored already :-(	8	3	9	5
41	;-) ok. I feel like john lennon.	18	0	2	53

42	What i mean was i left too early to check, cos i'm working a 9-6.	19	1	0	65
43	Have you been practising your curtsey?	10	7	3	24
44	:-(sad puppy noise	4	0	16	-32
45	Okay but i thought you were the expert	4	2	14	-21
46	Can not use foreign stamps in this country.	4	6	10	-15
47	Can not use foreign stamps in this country. Good lecture .	13	3	4	34
48	sorry, no, have got few things to do. may be in pub later.	8	2	10	-4
49	Sorry . I will be able to get to you. See you in the morning.	10	2	8	11
50	Sorry I was at the grocers.	10	3	7	10
51	Hi my email address has changed now it is	9	11	0	35
52	Hello! Good week? Fancy a drink or something later?	18	0	2	49
53	Hello- thanx for taking that call. I got a job! Starts on monday!	18	1	1	65
54	Miss ya, need ya, want ya, love ya.	8	1	11	2
55	Well I might not come then...	2	0	18	-43
56	Well done and ! luv ya all	19	0	1	87
57	Velly good, yes please!	18	0	2	72
58	Will be september by then!	15	4	1	42
59	I didn't get the second half of that message	4	4	12	-19
60	Ok cool. See ya then.	15	3	2	43
61	Not sure I have the stomach for it ...	2	0	18	-40
62	:-(that's not v romantic!	2	0	18	-41
63	Lovely smell on this bus and it ain't tobacco...	17	1	2	35
64	I wonder if you'll get this text?	9	2	9	7
65	, how's things? Just a quick question.	12	4	4	17
66	At home by the way	6	6	8	-6

67	Tee hee. Off to lecture, cheery bye bye.	13	3	4	19
68	anyway, many good evenings to u!	17	1	2	42
69	Man this bus is so so so slow. I think you're gonna get there before me	1	0	19	-53
70	whatever, im pretty pissed off.	3	2	15	-49
71	Oi when you gonna ring	6	1	13	-16
72	Did u find out what time the bus is at coz i need to sort some stuff out.	8	3	9	-5
73	Ho ho - big belly laugh! See ya tomo	14	2	4	31
74	... Are you in the pub?	13	6	1	28
75	Now thats going to ruin your thesis!	3	1	16	-45
76	Well I'm going to be an aunty!	12	1	7	18
77	Wow v v impressed. Have funs shopping!	18	1	1	56
78	See you there!	17	2	1	52
79	Have you not finished work yet or something?	3	1	16	-37
80	:-) yeah! Lol. Luckily i didn't have a starring role like you!	14	0	6	18
81	Hi hope u get this txt$\tilde{\text{j}}$ourney hasnt been gd,now about 50 mins late I think.	2	0	18	-42
82	Hiya, probably coming home weekend after next	14	5	1	44
83	Hiya, had a good day? Have you spoken to since the weekend?	13	4	3	24
84	Hello! How r u? Im bored. Inever thought id get bored with the tv but I am. Tell me something exciting has happened there? Anything! =/	8	1	11	-3
85	Okey dokey, i'll be over in a bit just sorting some stuff out.	14	6	0	42
86	Should I have picked up a receipt or something earlier	8	3	9	-3
87	Hey! Congrats 2u2. id luv 2 but ive had 2 go home!	7	3	10	-5

88	Okay, good, no problem, and thanx!	15	3	2	32
89	Thought we could go out for dinner. I'll treat you! Seem ok?	17	1	2	48
90	Are you driving or training?	8	8	4	12
91	Was the farm open?	11	8	1	23
92	Thought I didn't see you.	9	6	5	7
93	Am on my way	9	8	3	8
94	Only just got this message, not ignoring you. Yes, i was. Shopping that is	4	0	16	-36
95	This weekend is fine (an excuse not to do too much decorating)	5	7	8	-10
96	Forgot you were working today! Wanna chat, but things are ok so drop me a text when you're free / bored etc and i'll ring. Hope all is well, nose essay and all xx	16	1	3	51
97	I have lost 10 kilos as of today!	15	2	3	55
98	Everybody had fun this evening. Miss you.	17	1	2	72
99	Not tonight mate. Catching up on some sleep. This is my new number by the way.	12	6	2	29
100	That's a shame! Maybe cld meet for few hrs tomo?	13	3	4	28
101	I had a good time too. Its nice to do something a bit different with my weekends for a change. See ya soon	19	0	1	71
102	Lol! Oops sorry! Have fun.	11	5	4	21
103	No worries, hope photo shoot went well. have a spiffing fun at workage.	17	1	2	51
104	You know, wot people wear. T shirts, jumpers, hat, belt, is all we know. We r at Cribbs	11	9	0	24
105	Men like shorter ladies. Gaze up into his eyes.	13	3	4	33
106	I think I'm waiting for the same bus! Inform me when you get there, if you ever get there.	16	4	0	52

107	Indeed and by the way it was either or - not both !	11	3	6	17
108	I'm really sorry i won't b able 2 do this friday.hope u can find an alternative.hope yr term's going ok:-)	6	1	13	-23
109	You all ready for a big day tomorrow?	11	4	5	27
110	have a good weekend.	15	4	1	32