Haptic Responses to Emotional Stimulation

Deepa Mathew

Haptic (the sense of touch) technology is evolving rapidly and prevalent in our modern world; so it is only natural to use haptic technology to better understand and influence emotions in human beings. The purpose of this study is to understand if and how facial expressions such as anger and happiness affect haptic responses and how haptic technology can be used to capture the response. The main research question for this study was to find if different facial expressions affect the force and duration of touch exerted by participants and if there were any significant differences between gender?

In this study, a haptic device were used to sense and measure applied force (in Newton) and duration of touch (in milliseconds). A pilot test was conducted to study if there was any significant effect on the force and duration of touch when facial stimuli of anger and happiness were displayed. The calculated mean results were promising and so the experiment was repeated with new set of 20 participants. The ratings for each facial stimulus were also collected from participants. The mean values from the main experiment also yielded similar results as in the pilot test. The results from the statistical analysis suggest that the force of touch for anger expression is significantly stronger than happy expression. There were no statistically significant effect on the force and duration of touch across gender. The differences between mean ratings of the facial expressions for valence and arousal were all statistically significant except between the ratings of arousal for happy and neutral expressions. There were no statistically significant differences of ratings for arousal and valence across gender.

Based on the findings, it can be concluded that facial expressions of anger and happiness could influence the force of touch and that there is no significant variation between genders. This information would be used in Human-Computer Interaction (HCI) to measure or detect user's emotional responses inconspicuously.

Keywords and terms: haptics, sense of touch, tactile, emotions, facial expressions

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1. Introduction

Touch is one of the five senses and an extremely important sense. It is the first sense to develop before all other senses in the foetus and the last sense to fail in senility [Contributors, 2012]. Touch is founded on nerve receptors in the skin that dispatch electrical messages through the afferent neurons to the brain that interprets these electrical signals. The touch receptors mostly recognise heat, cold, pain, or pressure [Coon, et al. 2008]. Research has shown that touch has phenomenal psychological influences to human development, coaxing, healing and reducing anxiety and stress. [Mason et al. 2012]

The sense of touch, also referred to as *haptics,* allows us to feel (cold, heat, pain, pressure or surface texture), perceive and also interact with the surroundings. Likewise, haptic technology refers to the technology of touch that interacts with the user by applying vibrations, forces or motions to the user via the sense of touch [Robles-De-La-Torre, 2010]. This mechanical stimulation is used to mimic real touch and also to create haptic virtual objects. Haptic technology is notably obtaining popularity in this emerging high-tech world as it can provide the sense of touch in virtual and in real environments.

Haptics is also a form of nonverbal communication. Different cultures have different styles for greeting people. In some cultures, people greet each other with a hug and kiss on the cheek or just shake hands. These are a form of nonverbal communication expressing mutual respect and acceptance. In haptic technology, the same concept is used but in a different approach. Information can be communicated or accessed through haptic technology. For instance, mobile phones have vibration alerts and feedback, which are also a form of haptic feedback to alert the user. Furthermore, haptic feedback is also used in touch screen devices when swiping your finger across the screen or tapping an icon, and in video games to provide the user with a more realistic feeling of touch.

Emotions play an important role in our daily life and haptics has a great influence upon triggering different types of emotions. "Emotion is often the driving force behind motivation, either positive or negative" [Gaulin & McBurney. 2001]. Different emotions generate different facial expressions. Therefore, directly or indirectly, haptics, emotions and facial expressions are interconnected. The challenge is to understand how and to what level they are interconnected and how to use that information to create or design a better interaction model.

There has been a number of studies done on how facial stimuli and stimulation influences emotions and how to recognise different haptic input and output stimuli but not much research done on how external facial expressions and emotions influence the perceiver's haptic response.

1.1. Objectives and Motivation

This thesis examines the effect of facial expression of emotional stimuli on haptics. The primary focus of this thesis is to study how the facial expressions of anger, happiness and neutral faces influence haptic responses. Facial stimuli with no expressive changes on the face were used to find the medium between angry and happy emotions.

The importance and an interest in the sense of touch inspired me to choose this thesis topic to better understand why and how the facial expression of emotions influences the sense of touch. Based on the findings from this study, the latter can assist in understanding and improving future studies in developing a better haptic system to help deal with emotions for a better quality of life. Perhaps in the future it could be possible to design a mobile touch screen that could be used to detect a person's emotional state of mind unobtrusively and help them in dealing with emotions if needed. This might be especially beneficial to individuals with autism or other challenged people who have difficulty in communicating, expressing and dealing with their emotions.

In this thesis, two experiments were conducted. First a pilot test was conducted to decide if there was indeed any significant differences in the manner people touch when different facial expressions of emotional stimuli were displayed to them and if future detailed experiment needed to be done or not. Since the pilot test mean value results seemed promising, the experiment was repeated with new set of participants (10 male and 10 female) and statistical analysis of variance was conducted with all the data collected to find if it is statistically significant.

1.2. Thesis Structure

This thesis describes how facial expressions of emotional stimuli affect our haptic response. Further, details of the research process, results and the implications of the findings are presented.

In section 2, an overview of related work and its relevance to the current work is presented. In section 3, the methods used and the results for the pilot test are discussed. In section 4, the methods used and the results of the main experiment are presented. In

section 5, the overall findings, possible future research, the conclusion with the contributions of this work and suggestions for improvements are presented. Finally, in section 6, the summary of this thesis is presented.

2. Related Work

This section provides an overview of related literature, beginning with an overview of some of the major areas of haptics research, particularly focusing on projects related to touch, emotions, facial expressions and haptics that motivated and directed this thesis work. More detailed discussions of related work are included in each subsequent section, placed specifically in the context of the work presented.

2.1. Importance of Touch

In 1958, Harry F. Harlow, a famous psychologist, conducted experiments on monkeys. He focused his research especially on the rhesus monkeys as they have over 90 percent genes in common with humans. He found that infant rhesus monkeys chose surrogate mother covered with soft terry cloth (as shown in Figure **1**), that provided contact comfort over a bare mesh wire surrogate mother with milk dispenser that provided only nourishment [Harlow, 1958].

Figure 1. Infant monkey with a surrogate mother with soft terry cloth (Published with written permission from Harlow Primate Laboratory, University of Wisconsin-Madison)

Harlow concluded that it was the touch that encouraged endearment-like behaviour and not the food. This research on touch underlined the advantages of early haptic contact and the disadvantages of touch deprivation [Harlow, 1958].

Harlow's studies recognised that touch-deprived monkeys displayed stereotypical irregularity in their development and behaviour. These monkeys were occupied with embracing themselves and were not interested in their surroundings. In the presence of other monkeys, they tended to get anxious and tried to avoid interacting with other monkeys. Whenever they did interact with other monkeys they were very aggressive and disliked being touched and as a result, they also had difficulties finding a partner [Field, 2001].

Further research has found strong evidence that a lack of nurturing touch causes memory shortage, sickness, anxiety, and aggressive behaviour. Touch deprivation not only leads to intricate psychological, physical and emotional anguish, but also can even cause death. It is touch that promotes the feeling of security and good physical, mental and emotional health [Harlow, 1958]. Many researchers in their studies have also reported that touch reduces both physiological and perceived stress. Touch decreases the level of stress hormones such as cortisol, and increases the level of other hormones such as oxytocin, that stimulate social bonding and wellness [Hertenstein, 2009].

As mentioned earlier, haptics is the sense of touch and there is enough evidence to believe that touching and being touched are essential for a healthy life. Caressing and emotional involvement promote early childhood development. Children who do not receive enough caressing and emotional attention are at a greater risk of behavioural, emotional and social problems as they grow up [Harmon, 2010]. In spite of being well nourished and intellectually stimulated, a child without ample human touch can be impaired in his mental, emotional and even physical growth. This can potentially affect the child for years to come. According to a May 2010 article in *Scientific American*, orphaned children who did not receive enough caressing early in their childhood had different levels of oxytocin and vasopressin hormones. These hormones are essential for social bonding and these children had different hormonal levels even after a few years of being placed with a family [Blackwell, 2000].

2.2. Haptic communication

The sense of touch can be used for communicating feelings or information and this kind of communication method refers to haptic communication. A person can express or communicate their emotions such as joy, love, hatred or anger with touch. For instance,

painful or unpleasant touch such as kicking, punching, spanking, pinching, strangling, is perceived as negative touch that is expressed with anger or hatred and is considered a form of abuse. On the other hand, hugging, kissing or caressing is considered as positive touch, expressed with love and joy, and can be perceived as sexual or non-sexual touch [Knapp, M., Hall, J., & Horgan, T, 2013].

Touch is a very powerful means of expressing one's feelings, but it can be perceived in different ways in different cultures and age groups. In many of the western cultures it is common to hug and kiss on the cheek when greeting, especially between a man and a woman, and handshaking is reserved for more formal greetings [Remland et al., 1995]. Touch, as a form of greeting is a sign of respect and kindness. However, in some other cultures, it may not be appropriate and could be perceived as disrespectful and offensive for a man to touch (as a form of greeting) a woman who is not an immediate family member.

Face-to-face interactions represent a form of communication where touch can be a fundamental component inasmuch as emotions are expressed primarily through facial expressions, voice and touch [Bailenson et al, 2007]. In simple actions such as a handshake, the force and the style of holding hands can communicate one's personality or intentions without one having to express oneself verbally. A pat on the back or a hug can communicate a feeling of well-being, a positive emotion, even arousal, depending on the context, situation and the person involved [Jones, S. E., & Yarbrough, A. E., 1985].

Apart from human touch, technology using vibration or force feedback -such as the vibration or tactile feedback used in mobile phones-, this technology is also a type of haptic communication to alert or notify the user. Haptic feedback is currently used in mobile phones, touch screen devices and video games to give users a certain degree of feedback, although this has not yet reached its full potential. The addition of haptic feedback and recognition opens a new dimension and experience in massively multiplayer online games (MMOGs) and massively multiplayer online role-playing games (MMORPGs), where the users connect online with thousands of players in real-time interaction and communication [Chan & Vorderer, 2006].

2.3. Human Emotions and Facial Expressions

Human emotion is a deep psycho-physiological process. This interacts with the biochemical processes in the human body and the surrounding external environmental

influences. Human emotion mostly involves "physiological arousal, expressive behaviours and conscious experience" [Myers, 2004].

Emotions play a vital role in human behaviour and also in social interactions. In face-to-face communications, emotions are communicated not only via facial expressions but also by voice, gesture, posture, hand signals and touch [Cassell & Thorisson, 1999; Collier, 2014].

Modern psychology claims that emotion, behaviour and cognition have an effect on each other. Each emotion expressly affects human incentives, nervous system performance, learning, physical action, physiological arousal and social communication. For instance, the emotion of anger causes trembling and aggressive behaviour [Plutchik, 1991].

Common types of emotions are anger, disgust, fear, joy, sadness, surprise and calmness. Anger is an emotion that triggers fight or flight response. Human emotions and facial expressions are interlinked. Facial expression is a manifestation of emotions and is mostly universal. Different emotions trigger different facial expressions. In their book *E.S.P.: Extraordinary Selling Principles*, Anne Liebroder and Lawrence Liebroder characterised different facial expressions. The characteristics of the seven most common universal facial expressions are described below:

- *"**Anger**: Eyes wide and staring; eyebrows pulled down (especially in middle); wrinkled forehead; flared nostrils; mouth flattened or clenched teeth bared; jutting chin, red face.*
- ***Calm**: Relaxed facial muscles and steady eye gaze. Perhaps mouth turned up slightly at sides in gentle smile*
- ***Disgust**: Eyes and head turned away; nostrils flared; nose twisted in sneer; mouth closed, possibly with tongue protruding; chin jutting.*
- ***Fear**: Eyes wide, closed or pointing down; raised eyebrows; mouth open or corners turned down; chin pulled in; head down, white face.*
- ***Happiness/joy**: Mouth smiling (open or closed); possible laughter; crows-feet wrinkles at sides of sparkling eyes; slightly raised eyebrows; head level.*
- ***Sadness**: Eyes cast down and possibly damp or tearful; head down; lips pinched; head down or to the side.*
- ***Surprise**: Eyes wide open; eyebrows raised high; mouth dropped wide open with consequent lowered chin; head held back or tilted to side"* [Liebroder et al., 2012]

According to Nico H Frijda (1986), emotions trigger the state of arousal or valence when subjected to emotional stimulation. The term 'arousal' has both a physiological and a psychological connotation. It is the state of mind where the brain is alert and conscious. Researchers argue that an unconscious person cannot be in a state of arousal [Frijda, 1986]. The state of being aroused can be expressed both as a negative emotion such as anger and as a positive emotion such as happiness. The term 'valence', used especially in discussing emotions, means both *positive valence* if it refers to an essential attractiveness that is perceived to an incident, situation or context, and *negative valence* when referring to an aversion that is perceived thereto [Frijda, 1986].

One of the most important ways for humans to transmit social information, that is to say to express their internal emotions externally, is through facial expressions. In the 19th century, Charles Darwin (1872) wrote that facial expressions are biological and universal for the human culture. Psychological investigations done by Paul Ekman (1975), an American psychologist, corroborated the universal character of facial expressions for the six basic emotions: "happiness, sadness, fear, anger, surprise, disgust and neutral are universal" [Ekman, 1975]. In this study, four best represented photographs each for anger, happiness and neutral were chosen carefully from a large collection of pictures that were developed by Drs. Paul Ekman and Wallace V. Friesen (1975).

There are studies that clam that when humans are exposed to emotional facial expressions, they automatically react with recognizable facial electromyographic reactions in emotion-relevant facial muscles. A study done by Dimberg, et al. (2000) shows that both happy and angry emotional reactions can be unconsciously aroused, especially the most important aspects of emotional face-to-face communication can occur in an unconscious state [Dimberg et al. 2000]. Another study presented that women appear to have an eminent capability to perceive and react to positive facial emotion at an instinctive processing level compared to men [Donges et al. 2012]. Therefore, in this study, a gender as between subjects factor was also considered.

Margaret Bradley and Peter Lang (1994) presented a study on measuring emotion. They designed a non-verbal pictorial assessment technique that directly measures the pleasure, arousal, and dominance associated with a person's affective reaction to a wide variety of stimuli, that they call as Self-Assessment Manikin (SAM). In their study, they compared reports of affective experience obtained using SAM that requires just three simple judgments, to the Semantic Differential scale devised by Charles E.

Osgood (1964) that requires 18 different ratings [Bradley & Lang, 1994]. Similar to SAM, the semantic differential scale provides a mechanism to measure a person's emotional response to external stimuli using the three dimensions: pleasure, arousal and dominance [Bradley & Lang, 1994]. Their study found a correlation between pleasure and arousal for SAM and Semantic Differential scale.

Emotional response can be measured in at least three different systems - affective reports, physiological reactivity, and overt behavioural acts [Lang, 1969]. In this thesis, the participants were asked to rate the facial stimuli using the Semantic Differential 9-point rating scale ranging from -4 to +4, with 0 representing the center segment of the scale.

2.3.1. How facial emotion expressions affect human perception

Over the decades, there has been several studies and debate over the "anger superiority effect" versus the "happiness superiority effect". The studies done by Christine H. Hansen & Ranald D. Hansen (1988) and Öhman, Lundkvist, & Esteves (2001) conclude that angry faces are more rapidly detected in a crowd of faces, thus supporting the anger superiority effect also popularly known as anger "pop-out".

Christine H. Hansen & Ranald D. Hansen (1988) reported that, an angry or aggressive face popped out in a group of happy faces and that it was found faster than a happy face in an cluster of angry faces, perhaps as a result of a pre-attentive, parallel search for clues of direct threat or danger. Angry faces were found more efficiently in neutral crowds than were neutral faces in angry crowds. In addition, angry faces were found more efficiently in happy crowds than were happy faces in angry crowds. Their finding was called as the "face-in-the-crowd effect" (FICE). Similarly, Öhman et al. (2001) reported that aggressive angry faces were more faster and precisely detected than were other negative faces such as sad or "scheming". This conveys that the threat circumstance can be ascribed to threat rather than to the negative valence or the uniqueness of the target exhibit [Öhman et al. 2001].

Contrary to those studies that suggest angry faces "pop-out" of crowds, Becker, et al. (2011) review of the literature found inconsistent data for the effect and suggested that low quality visual confounds could not be disregarded as the driving force behind the anger superiority effect. Their experiments showed no evidence that angry faces popped out of crowds or even that they were efficiently spotted. Instead, their experiments revealed a search irregularity backing happy faces. The happiness superiority effect was transcend even when obvious intuition confounds like the

contrast of white exposed teeth that are usually displayed in smiling faces were removed in the happy displays. Instead of attributing this effect to the presence of innate happiness indicators, they speculated that the human expression of happiness has evolved to be more visually discriminable as it communicates less ambivalent expression compared to the other facial expressions [Becker et al. 2011].

2.4. Expressing and recognising emotions through haptic devices

Researchers are trying to understand and improve the dynamics of expressing and recognising emotions with the use of haptic devices. Several studies have been conducted on this topic such as the one done at Stanford University by Bailenson et al (2007). This research was based on participants using a 2-DOF force-feedback joystick to express seven emotions. Various measurements of the forces produced and the subjective ratings of the complexity in expressing those emotions were examined. Then in a second experiment, they used a separate group of participants to recognise the recordings of emotions generated in the first experiment. Finally, a third experiment consisted of pairs of participants trying to express the seven emotions using physical handshakes.

Results indicated that humans were only marginally better when recognising emotions via virtual interpersonal touch than as people expressing emotions through non-mediated handshakes [Bailenson et al. 2007].

Another study done by Hertenstein, et al. (2006) on how touch can communicate distinct emotions using an encoder to touch and a decoder to feel the touch could accurately communicate distinct emotions such as; anger, fear, disgust, love, and sympathy [Hertenstein et al. 2006]. The results showed that it can communicate anger via touch more precisely than other emotions such as fear and love [Hertenstein et al. 2007].

2.5. People with functional limitations and role of haptics

The Braille system used by the visually impaired to read and write is also a type of haptic communication where the visually impaired can read via sense of touch. Touch is very crucial for visually impaired people as they strongly rely on touch to sense and feel the physical surroundings. The visually impaired need touch to grow, develop, learn and communicate. In the study '*Vibrotactile Masking Experiments Reveal Accelerated Somatosensory Processing in Congenitally Blind Braille Readers*' published in the October 27 2010 issue of the Journal of Neuroscience, it was found that people born

blind are able to detect haptic information faster than people with normal vision [Bhattacharjee et al. 2010].

Another area of interest where touch plays a crucial role is people with the autism spectrum disorder. The majority of children with autism spectrum disorders have problems with communication, especially with speech. Using a touch screen and specially designed application for these children can help them to communicate and also to learn.

Studies on autism have revealed the importance of haptics and how a machine or device can be used to help pacify hypersensitive people if they could not turn to other human being for comfort [Grandin, T. 1992]. The deep pressure applied to the body led to a calming effect. Temple Grandin, a professor at Colorado State University and a person with autism, invented the squeeze machine also called as hug machine to cope with her anxiety. This device is designed to provide deep pressure stimulation across the body to help calm them down [Edelson, et al. 1999].

The concept of using haptic device to influence or detect emotions is a key factor in HCI. In depth research is needed when designing and developing device or application for measuring or detecting user's emotional responses unobtrusively to help people with autism or other challenges.

Thus overall, this section provided an overview of the importance of haptics and emotions related studies that motivated and directed this thesis work. In the following chapter, the pilot test process and the results on how people responded with touch to different facial stimuli are discussed.

3. Experiment 1 (Pilot test)

A pilot test with 24 participants with mean age of 40 years was initially conducted to study how people responded with touch to angry, happy and neutral facial stimuli. Statistical analysis was conducted to verify the findings with the data collected during the experiment.

The main research question for this experiment was to find, if different facial stimuli affect the force and duration of touch exerted by participants?

3.1. Methods

The main aim of the pilot test was to study how 2D facial stimuli of different emotions such as anger, happiness and neutral influence the manner people touched.

3.1.1. Participants

There were 24 participants, 14 males and 10 females between the ages of 20 to 58 years old who took part in this experiment. The participants included people mostly from northern Europe (Finnish & Swedish) and a few from Asian background (Indian & Pakistani). The participation was voluntary and all the participants had normal or corrected to normal vision. At the end of the experiment, each participant was asked to sign a consent form and a copy of the form was returned to each of them. See Appendix 1 and Appendix 2 for the forms used for the experiments.

3.1.2. Facial stimuli

Four pictures of facial affect, each for anger, happiness and neutral (total of 12 pictures) were chosen carefully from 110 black and white pictures developed by Drs. Paul Ekman and Wallace V. Friesen (1975). (Due to copyright protection, the pictures are not presented in this thesis). Ekman and Friesen developed the facial stimuli by photographing "posers who were trained to contract or relax different facial muscles associated with various facial expressions" [Ekman and Friesen, 1975].

In this study, the photographs of the facial stimuli for anger, happiness and neutral were chosen based on the highest percentage that was scored on consistent agreement among the groups of observers in Ekman and Friesen's study about the emotion being expressed. In addition, gender was balanced across picture series. Two male and two female pictures for each emotion were chosen.

3.1.3. Apparatus

3.1.3.1   Hardware

Interlink electronics 1.5" square Force Sensing Resistor (FSR) and Phidget Interface Kit 8/8/8 as shown in Figure **2** were used for this experiment to record the force and duration of touch.
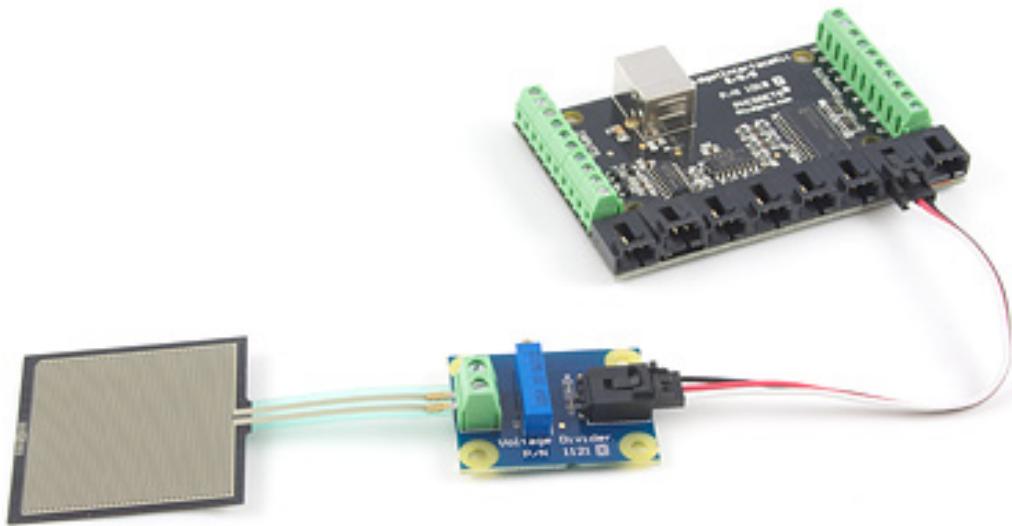

Figure 2. Interlink FSR connected with PhidgetInterfaceKit 8/8/8 (Published with written permission from Phidgets, Inc.)

The Interlink Force Sensing Resistor (FSR) uses a 1.5" (12.7mm) square pad to sense applied force. FSR is a very thin, robust, polymer thick film device as shown in Figure **3** that decreases in resistance when increased pressure is applied to the surface of the sensor [Phidgets, Inc. 2010a].
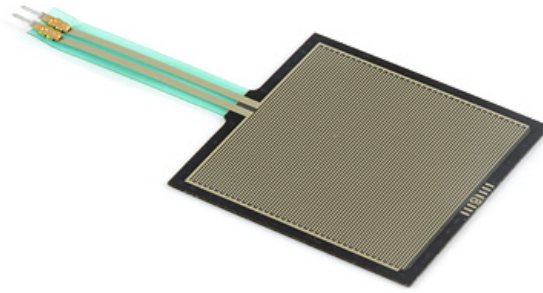
Figure 3. The Interlink FSR (Published with written permission from Phidgets, Inc.)

The Interlink FSR is plugged directly into the Phidget interface kit 8/8/8 as shown in Figure **4** board using a cable included with the sensor (as shown in Figure **2**). The analogue inputs are used to measure continuous quantities, such as pressure and duration of touch [Phidgets, Inc. 2010b].
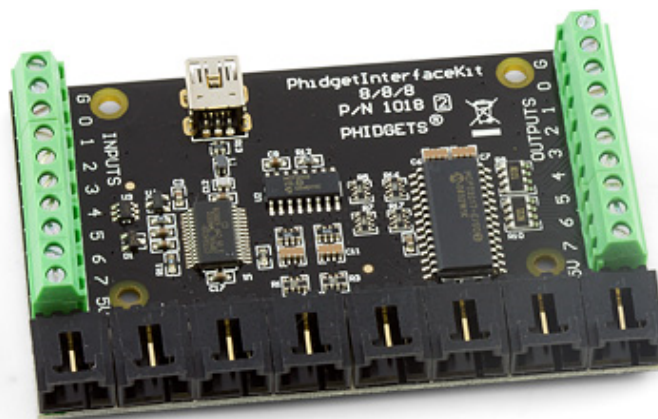

Figure 4. Phidget Interface Kit 8/8/8 (Published with written permission from Phidgets, Inc.)

The haptic device (Interlink FSR connected to the PhidgetInterfaceKit 8/8/8) was plugged directly to the laptop via USB port. All the electronics were concealed inside a cardboard box and secured with duct tape. Only the Interlink Force Sensing Resistor was revealed outside, as shown in Figure 5.

Figure 5. The haptic device connected to the laptop via USB port

3.1.3.2   Software Environments

The laptop used for the experiment had Windows 7, 32-bit Operating System. The .NET framework was installed for the haptic device installer to automatically install all the needed libraries to run the haptic device [Phidgets Inc, 2010c].

The system logs collected information for each instances (i.e. force and duration of the touch when the participants tap the haptic device after viewing the image that was displayed on the screen). Visual Basic (VB) 6.0 and JavaScript programming languages were used to design and create the test application for the experiment. The sample code and examples were downloaded from the Phidget website and edited to suit the experiments needs. MySQL database was used to store and retrieve the data collected during the experiments.

In addition to the test application, a local (localhost) website was built as a front-end, using PHP and HTML to fetch and display the participant details that was collected in the experiment. The details were fetched from the MySQL database. The MySQL, PHP and HTML coding were done manually. EditPlus editor was used for coding. Internet Explorer browser was used to view the details and the results from the data collected. The data collected during the experiment from each participant were displayed in a tabular form on the browser and the test results would be downloaded in CSV file format. The CSV file was converted into Excel file format for analysing the data.

Google Form was used to design and store the ratings collected from each participant. A local copy was created to display the facial stimuli used for the experiments as the images are copyright protected and cannot be uploaded online. The ratings for each facial stimulus were collected and stored in Google Forms using a private account. This data was also saved in Excel file format for analysis purposes.

3.1.4. Procedure

The participants were told a cover story explaining that the purpose of the experiment was to find out how fast the participant could react to images displayed on the computer screen by tapping on the Force-sensing resistor (FSR). The task was to tap the FSR as fast as possible - immediately after the image had appeared on the screen.

After the experiment was completed, the participants were appraised about the actual intention of the experiment. It was explained that the purpose behind the experiment was to measure the force of touch and had little to do with the duration of touch

The experiment was conducted in a quiet isolated study room without any external disturbances or distractions. The participants were asked to switch-off their mobile phones to avoid any distractions during the experiment. The participant was seated at a table facing the laptop screen. The haptic device was connected to the laptop and the test application was started when the participant was ready to begin. The participant was acquainted with the FSR and the test procedure through a practice test. This practice test consisted of five different facial stimuli not used in the actual experiment. This practice test was not recorded, as its purpose was to familiarise the participant with the FSR and with the testing procedure.

The moment that the participant had got familiar with the FSR and the procedure was explained to them, the actual test began. In the beginning of the test, each participant was asked to enter their personal details such as: name, age, gender, occupation and nationality. After all the required information was entered, they could click the 'Start Test' button.

When the 'Start Test' button was selected, an image was displayed on the computer monitor and the participant had to tap the FSR as fast as possible. The tap on the FSR resulted in the immediate disappearance of the image and there was a pause for 3 to 5 seconds before a new image appeared automatically. They had to touch the FSR again to make that image disappear and the next image to appear. An interval of 3 to 5 seconds was used randomly between each display of image after tapping the FSR to

prevent the participants from subconsciously predicting when the next image appears. A total of 12 images were used for this experiment, out of which, four different facial stimuli of anger, happiness and neutral were used. Once the experiment was completed, the participants were given the consent form (see Appendix 1) to fill in and a copy of that form was returned to them.

The force of touch and the duration of touch were saved for each image and it can be viewed on the local web browser with the details of the participant (that was provided by the participant) and the test results. Figure **6** shows the screenshot of the 'Participant Details' page. The participant page displays details such as: name, sex, age, nationality, and occupation of the participant and a link to view the test results.
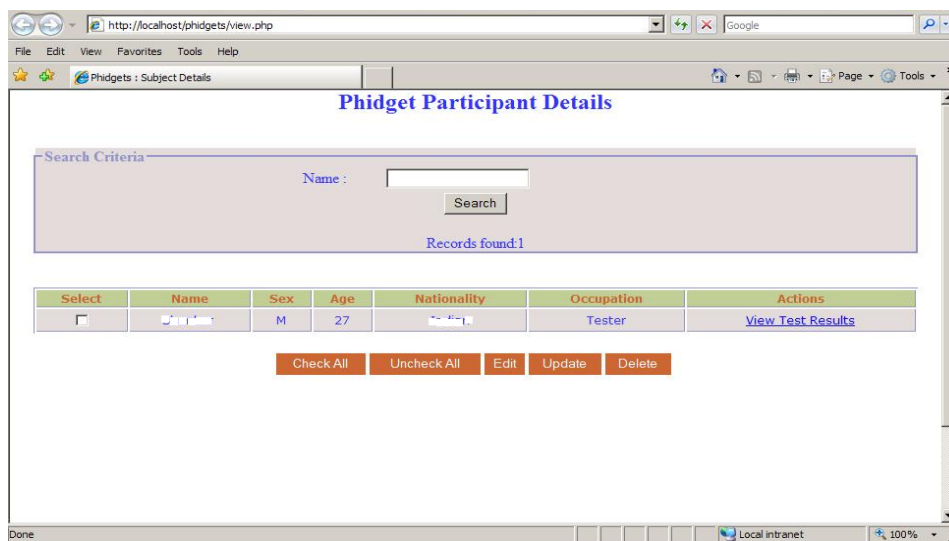

Figure 6. Screenshot of the results sheet (name and nationality are hidden for privacy reasons)

3.2. Results

The mean and Standard Error of the Mean (S.E.M) of force of touch and duration of touch for different facial expressions are shown in Figure **7** and Figure **8** respectively. The mean results show that the angry expression triggered more haptic force feedback and had less time duration of touch compared to the happy and neutral expression. Conversely, the happy expression triggered less haptic force feedback but more time duration of touch.
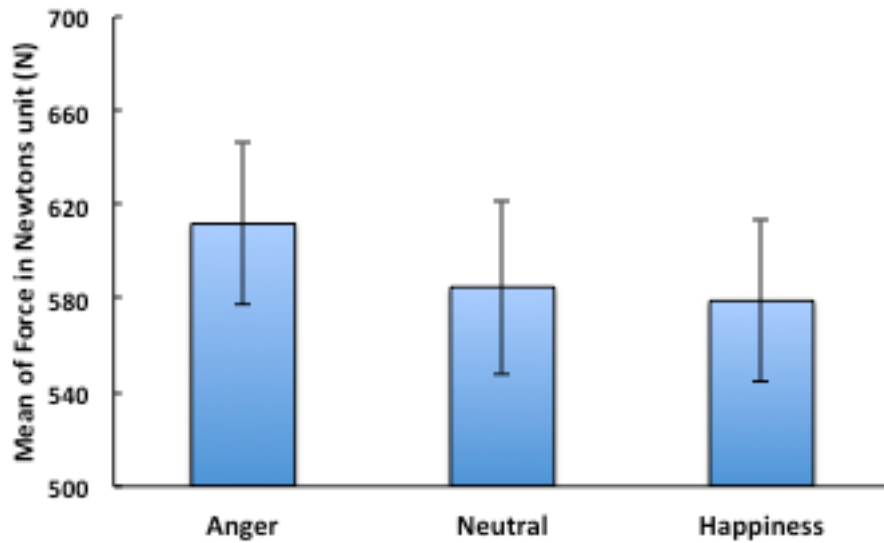
Figure 7. The means and S.E.M for force of touch for different facial stimuli

A one-way within subjects repeated measures Analysis Of Variance (ANOVA) was conducted to see if expression had an effect to the use of force applied on the force-sensing resistor.

The one-way within subjects repeated measures ANOVA revealed no statistically significant main effects of expression to the force of touch at, $F_{(2, 46)} = 1.381$, $p > 0.05$.

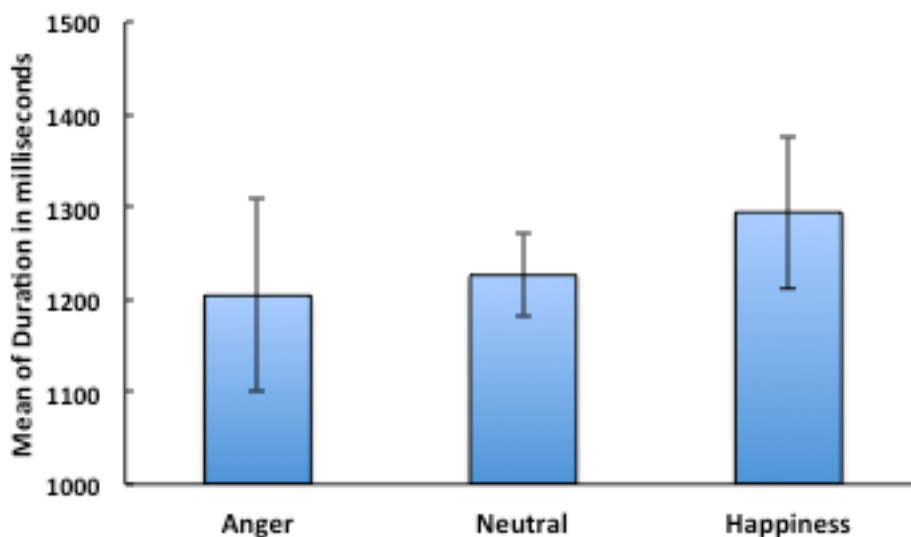Figure 8. The means and S.E.M for duration of touch for different facial stimuli

A one-way within subjects repeated measures ANOVA was conducted to see if expression had an effect to the duration of touch on the force-sensing resistor. The one-way within subjects repeated measures ANOVA revealed a statistically significant main effects of expression on duration of touch $F_{(2,46)} = .055$, $p > 0.05$.

4. Experiment 2

4.1. Methods

The experiment was repeated with new set of participants and in this round, the participant's gender was recorded alongside and in addition, the ratings of the facial stimuli were collected from each participant after the experiment was completed. Similar to the pilot experiment, the mean value for the force and duration of touch were calculated to analyse the variation in the touch. In addition, the statistical analyses of variance were also run to find if they are statistically significant.

The two main research questions for this experiment was to find:

1. If different facial stimuli affect the force and duration of touch exerted by participants?
2. If there were any significant differences between gender

4.1.1. Participants

There were 20 new participants, 10 male and 10 female, between the ages of 20 and 40 years who took part in this experiment. The participants were mostly students from the Tampere Technical University and the University of Tampere. They were from different ethnic groups of northern Europe and a few Asians. The participation was voluntary. All participants had normal or corrected to normal vision. At the end of the experiment, each participant was asked to rate the facial stimuli that were displayed during the experiment. Afterwards, they were asked to sign the consent form and a copy of the consent form was returned to them. The copies of the forms can be found in Appendix section.

4.1.2. Materials and Apparatus

The same Interlink Force Sensing Resistor (FSR) of 12.7mm square pad and Phidget interface kit 8/8/8 board as in the pilot experiment was used in this experiment to sense and measure applied force.

4.1.3. Design and Procedure

Similar to the previous experiment, the participants were narrated a cover story, stating that the purpose of the experiment was to find out how fast they could react to the images being displayed on the computer screen by tapping on the Force Sensing Resistor (FSR). During the experiment, different 2D facial stimuli of emotional

expressions were displayed. The task was to touch the FSR as soon as the image had appeared on the screen.

After the experiment, the participants were informed about the actual intention of the experiment. The procedure was identical to the pilot test, except that this time, after the experiment was completed, the rating for each facial stimuli used in the experiment was collected using two scales from SAM method. An online rating form was created with 9 rating scales from –4 to 4 as shown in Figure **9**. There were two questions under each facial stimulus that had to be rated by the participants:

1. How arousing or calming is this picture?
2. How pleasant or unpleasant is this picture?

The participants had to rate each of the facial stimuli that were displayed during the experiment according to how they felt about them.

Emotion Assessment

1. How Arousing or Calming is this picture? *

	-4	-3	-2	-1	Neither calm nor arousing 0	1	2	3	4	
Calming	◎	◎	◎	◎	◎	◎	◎	◎	◎	Arousing

1. How Pleasant or Unpleasant is this picture? *

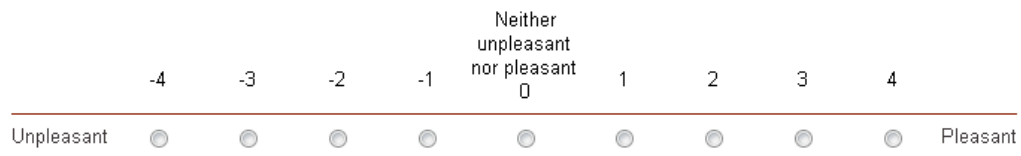|	-4	-3	-2	-1	Neither unpleasant nor pleasant 0	1	2	3	4	
Unpleasant	◎	◎	◎	◎	◎	◎	◎	◎	◎	Pleasant

Figure 9. Rating scale from –4 to 4 used to collect feedback of the facial stimuli

In addition, the gender of the participants was recorded in this round of experiment. Exactly as in the pilot test the participants were first acquainted with the haptic device and the test procedure through a practice test. Later when the participants were familiar with the FSR and the procedure was explained to them, the actual experiment began.

4.2. Results

4.2.1. Force of Touch

The mean and S.E.M values for the force of touch for each facial expression; angry, neutral and happy were calculated separately for both male and female participants. Figure **10** shows the graph representing the means and S.E.M for the force of touch.
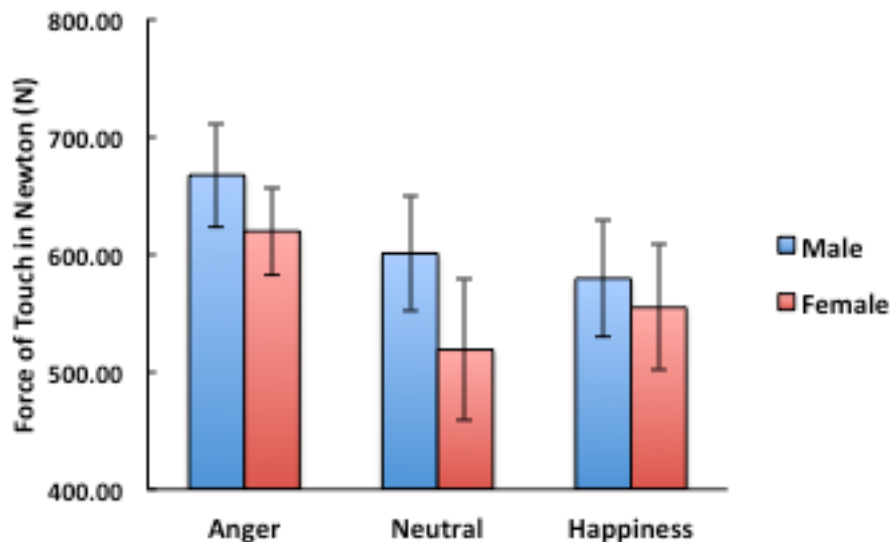

Figure 10. Means and S.E.M of force of touch across male and female

A two-way 2x3 (gender x stimulus) mixed ANOVA with gender as between subjects factor was performed to find out if there were any statistically significant differences in the force of touch for different expressions across gender.

Two-way analysis of variance with gender as a between subject and expression as a within subject factor showed a statistically significant main effect of expression $F_{(2, 36)} = 9.221$, $P < 0.05$. The main effect of gender was not statistically significant $F_{(1, 18)} = 0.621$, $P > 0.05$. The interaction of the main effects was not statistically significant.

Post hoc pairwise comparisons revealed that the use of force was stronger in response to angry expression than in response to happy expression (MD = 76.575, $p < 0.05$). The differences between responses to the angry and neutral expressions were also significant (MD = 83.850, $p < 0.05$). However, the differences between responses to happy and neutral expressions were not statistically significant (MD = 7.275, $p > 0.05$).

4.2.2. Duration of Touch

The mean and S.E.M values for the duration of touch for each facial expression were calculated separately for both male and female participants for the duration of touch. Figure 11 shows the graph representing the means and S.E.M for the duration of touch discretely for both male and female participants.
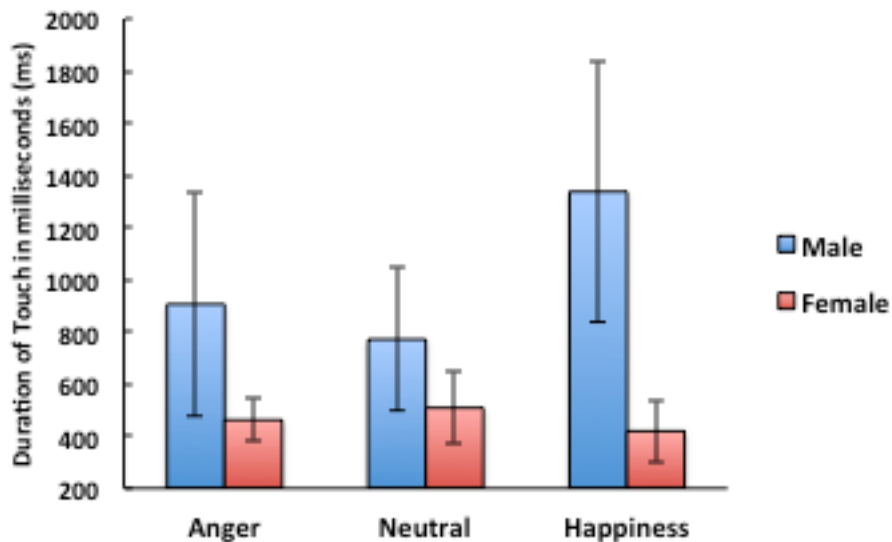

Figure 11. Means and S.E.M of duration of touch across male and female

The mixed 2x3 (gender x stimulus) ANOVA was conducted to see if there were statistically significant difference between the effects of gender and effects of expression on the duration of touch.

The analysis of variance with gender as a between subject and expression as a within subject factor showed no statistically significant main effect of expression $F (2, 36) = 1.446, P > 0.05$ and no main effect of gender $F (1, 18) = 1.918, P > 0.05$. The interaction of the main effects was not statistically significant either.

4.2.3. Ratings of the facial emotional stimuli for valence

The mean value for the ratings of the facial stimuli showed that the participants rated the expression of happiness to be more towards the pleasant side and the angry facial stimuli towards the unpleasant side.

However, few of the male participants rated the happy female facial stimuli as more arousing than the angry female facial stimuli. In addition, the participants did not feel that the happy male facial stimuli were very pleasant. The mean value for the

participant's ratings of facial stimuli was calculated separately for the male and female participants. The graph of mean and S.E.M's for ratings of valence separately for male and female participants are presenting in Figure **12**.
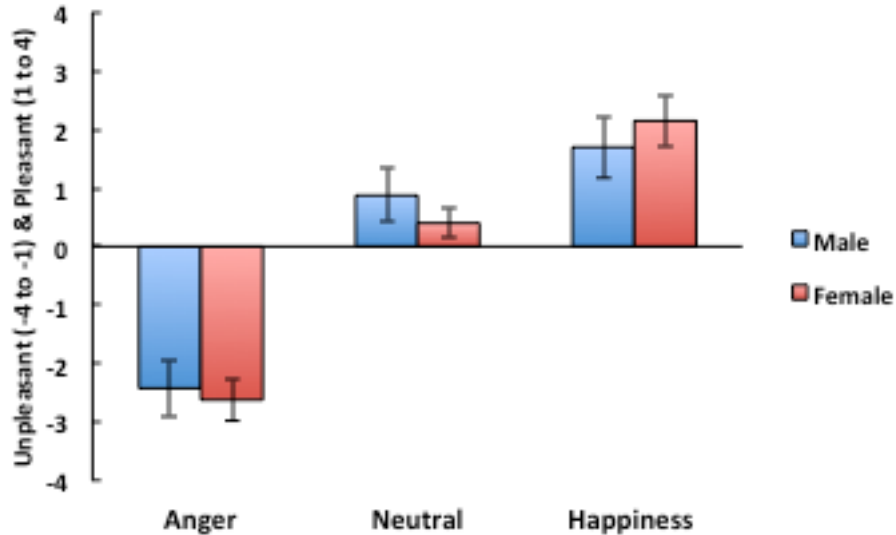

Figure 12. Means and S.E.M's of the ratings for valence across gender

The mean value for valance across gender shows that the male participants had rated higher for neutral facial stimuli. In contrast, the female participants rated high for happy facial stimuli. Therefore, it was decided to split the ratings data by gender to see the difference and a mixed 2x3 (gender x stimulus) ANOVA with gender as between subjects factor was performed to find out if there were any statistically significant differences in the participant's ratings for different facial stimuli between genders.

Two-way analysis of variance with gender as a between subject and expression as a within subject factor showed statistically significant main effect of valence expression *F (2, 36) = 106.474, P < .001*. The main effect of gender was not statistically significant *F (1, 18) = 0.131, P > .05*. The interaction of the main effects was not statistically significant.

Post hoc pairwise comparisons indicated that there was a significant difference between angry and happy expressions (MD = -4.450, p < 0.01), angry and neutral expressions (MD = -3.163, p < 0.01) and happy and neutral expressions (MD = 1.288, p < 0.01).

4.2.4. Ratings of the facial emotional stimuli for arousal

The mean value of the ratings for the facial stimuli collected shows that the participants rated the expression of anger to be more arousing and the neutral expression more towards the calming side of the bipolar scale.

The mean value for the participant's ratings of facial stimuli was calculated separately for the male and female participants. The graph of mean and S.E.M's for ratings of arousal separately for the male and female participants are presented in Figure **13**.
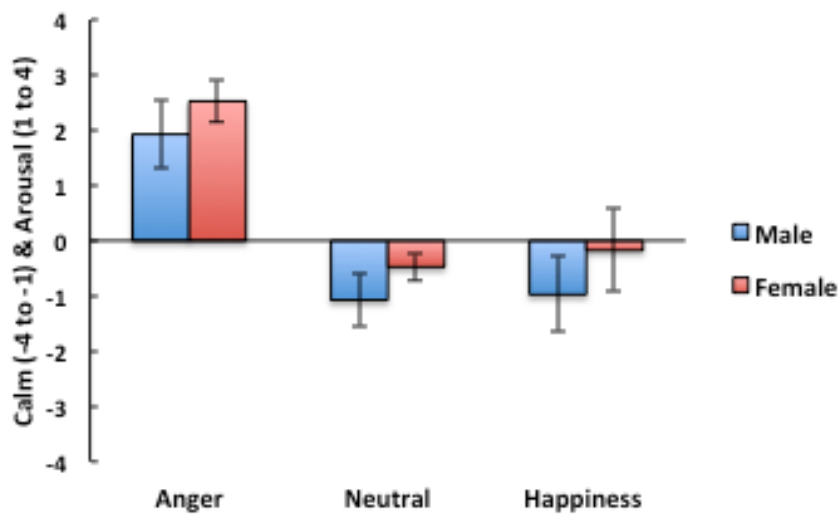

Figure 13. Means and S.E.M's of the ratings for arousal across gender

The mean value across gender shows that the male participants had rated higher for arousal for happy facial stimuli and the female participants rated high for angry facial stimuli for arousal. Therefore, a mixed 2x3 (gender x stimulus) ANOVA with gender as between subjects factor was performed to find out if there were any statistically significant differences in the participant's ratings for different facial stimuli between genders.

Two-way analysis of variance with gender as a between subject and expression as a within subject factor showed statistically significant main effect of arousal expression $F (2, 36) = 30.749, P < .001$. The main effect of gender was not statistically significant $F (1, 18) = 4.220, P = .055$. The interaction of the main effects was not statistically significant.

Post hoc pairwise comparisons indicated that there was a significant difference between angry & happy expressions (MD = 2.800, $p < 0.01$), and between angry & neutral expressions (MD = 3.000, $p < 0.01$). However, the differences between the ratings of arousal to happy and neutral expressions were not statistically significant (MD = 0.200, $p > 0.05$).

5. Discussion

The findings of this study showed that the stimuli were rated accordingly to the Ekman Friesen (1975) results so that angry, neutral, and happy faces were rated similarly using pleasantness dimension. The ratings of arousal showed further that angry expressions were significantly more arousing than neutral or happy expressions.

The mean value of the ratings collected showed that the participants rated the happy expression towards being more pleasant and the angry expression towards being more arousing. The mean value across gender shows that the male participants had rated higher for arousal for happy expression and valance for neutral expression. In contrast, the female participants rated high for angry expression for arousal and happy expression for valence. The ratings of valence and arousal are statistically significant across all participants expect for valence between happiness and neutral expressions. However, the mixed two-way ANOVA for arousal and valence ratings across gender revealed that the main effect of gender was not statistically significant.

Thus, it can be concluded that the participants rated the angry facial stimuli more arousing but were inconsistent in the ratings for the happy facial stimuli. Some rated it as more arousing and the others rated it as more pleasant.

Secondly, the test results from the pilot test looked promising as the mean value of the data collected showed that the force of touch was stronger and the duration of touch was shorter in response to anger facial compared to responses to happy and neutral expressions. The results showed that the force of touch was weaker and the duration of touch was longer for happy facial stimuli when compared to angry facial stimuli.

The mean values from the main experiment also yielded similar results as in the pilot test. The results from the statistical analysis for the main experiment showed that the use of force was stronger in response to angry expression than in response to happy and neutral expressions. However, the differences for force of touch between responses to happy and neutral expressions were not statistically significant. This results support the previous study reported by Christine H. Hansen & Ranald D. Hansen (1988) on the anger pop-out effect that anger as an emotion is more pronounced than happiness thus contribute to the study on anger superiority effect. In addition, also contributes to the study done by Hertenstein et al. (2007) that anger is communicated via touch more precisely than other emotions such as fear and love.

The results from the statistical analysis for duration of touch showed no statistically significant variations. Thus, it shows that there was no effect on the duration of touch for angry, happy and neutral facial stimuli.

The mean value across gender for force and duration of touch revealed that the male participants applied more force and duration of touch than the female participants. However, the two-way ANOVA showed that there was no statistically significant difference between the force and duration of touch across gender.

The findings suggest that observing facial expressions of emotions could subconsciously influence the haptic response. Emotions could be transferred via externals' facial expression subconsciously to our haptic response. It could even be possible to identify a person's emotional state of mind by their haptic response. A touch screen device can be used to record the touch and evaluate the persons emotions based on their force of touch.

To my knowledge, this is the first time an evaluation has been performed to analyse if there are any significant differences on haptic responses in correspondence to facial expressions. Although the number of participants used in this study is not sufficiently enough to make a scientific conclusion, the present results are promising and these findings could aid in designing intelligent systems to record and measure the user's emotional responses even inconspicuously if required.

There are seemingly endless possibilities for the application of these findings such as from gaming to autism research and stress control, as discussed next.

5.1. Gaming

As the gaming world evolves, it is increasingly becoming an individual activity with online collaborations, where interactions are virtual than physical. For instance; in massively multiplayer online games (MMOG) and massively multiplayer online role-playing games (MMORPGs), getting emotional haptic feedback from other players in the team who are not based in the same location, thus, remotely located, can improve the gaming experiences, increase social bonding between teams and provide a substitute for face to face communication. In addition to improving the gaming experience a haptic device could also be used to identify negative emotions such as anger and suggest options to manage anger. Thus assisting the user to lessen the deleterious effects that negative emotions can have on the user's psychological and physiological performance.

A study led by Harvard psychiatry professors, using video games to help kids with severe anger issues to gain control of their emotions, use a heart monitoring device attached to their finger to track the heart rate as they play the game [Harvard Magazine Inc., 2016]. The game is used as reinforcement and was reported that it enhanced child motivation for psychotherapy and strengthened the therapeutic relationship with the child [Brezinka, 2014].

This heart monitoring device could easily be replaced by a haptic device. For instance, Apple developed 'Force Touch', a pressure sensitive multi-touch technology, that enables touchpads and touchscreens to identify different levels of force applied to it's surfaces [Apple Inc., 2015]. This technology could be used to design and develop gaming applications that could detect the user's emotions and thus enable to help them with stress and anger management.

5.2. People with functional limitations

Human emotions and the sense of touch associated with it is crucial for better development and function in life and the findings from this study could be applied to cases where individuals are not comfortable with or are unable to express emotions verbally such as individuals with autism or other functional limitations. Introducing a haptic device that could record the applied force of touch to determine the emotion exerted by the individual could help others such as a care giver to better understand the situation and effectively help with it.

People born blind are able to detect haptic information faster than people with normal vision [Bhattacharjee et al. 2010], so individuals with vision impairments could benefit from using touchscreen readers with haptic feedback to feel or communicate the emotion of a person in a picture through haptics.

These are just few possibilities but more research is required to validate it. In addition, future studies are needed on how to introduce these findings into effective use in HCI.

6. Summary

The main purpose of this study was to understand how facial expressions for anger and happiness effect haptic response and how haptic technology can be used to recognise emotions. From this study it was found that the force of touch was stronger when the participants viewed the angry facial expression stimuli than when compared to the happy and neutral facial expressions stimuli. Thus, it could be concluded that different facial expressions could affect a person's haptic responses discretely. In addition, it was found that there were no noticeable variations in haptic responses between genders. The findings from this study not only provide a stepping-stone for future research but also it introduces a new dimension to human-computer interaction.

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Appendix 1

CONSENT FORM FOR: Emotional Communication through Haptics

Date: ___/___/____

DESCRIPTION

You were invited to participate in an experiment to study how facial expressions can affect haptic responses. In this experiment, different images of facial expressions of emotions are displayed and a touch sensitive haptic device is used. We are more interested in the force than reaction time you used when tapping the touch device.

RISKS AND BENEFITS

There are no expected risks or benefits involved with this experiment

DURATION

The experiment took approximately 10 mins

CONTACT INFORMATION

If you have any questions, concerns or complaints about this experiment, its procedures, risks and benefits, contact: Deepa Mathew

PARTICIPANT RIGHTS

By singing this consent forms:

· I confirm that I have read and understand the information sheet dated ………………. For the above study.

· I have had the opportunity to consider the information ask questions and have had these answered satisfactorily.

· I understand that my participation was voluntary and that I am free to withdraw at any time without any consequences.

· I understand that the data found from this experiment will be used only for research purpose and I give permission to use this information for research purpose only.

· I understand that my privacy is protected in experimental data and reports done based on that data

I agree to that my data can be used for this study.

_____

Name of Participant

_____   ___/___/____

Signature   Date

When completed, one copy for participant and one copy for the researcher (original) to be kept.

<div style="text-align: right">Appendix 2</div>

INSTRUCTION: Emotional Communication through Haptics

[MOBILE PHONES OFF]
[SIGNING THE CONSENT FORM – There will be 2 copies. 1 for each of us]
[Collecting the background information of the participant]

INTRODUCTION

The aim of this experiment is to find out how fast the participant can react to images displayed on the computer screen by tapping on the haptic touch sensor device. In the experiment different images of facial expressions will be displayed. Your task is to touch the haptic device as fast as possible immediately after the image has appeared on the screen. The experiment will take about 30 minutes in total.

INSTRUCTION FOR THE EXPERIMENT

The experiment begins with a practice trial. During the practice trial you will get familiar with the haptic touch sensor. After the practice trial there will be 6 different facial expressions of emotion displayed.

Practice trial

An image will be displayed and you are to tap the haptic touch sensitive device as fast as possible. Your touch will result in immediate disappearance of the image and your reaction time will be registered to the system log. Then there will be a pause of few seconds and a new image will automatically appear. Again you are to react fast in order to make the image disappear. You get to try that a few times (how many?) and when you are comfortable to proceed with the experiment then the experiment trial begins. Also feel free to ask any questions.

Experimental trial

The practice trial is now over. Do you have any questions? The experimental trial proceeds as the practice trial did, also the task is the same. The experiment lasts about 15 minutes. Do you have any questions? If not, you can start the experiment by selecting the "Start Test" button on the computer screen.