Communicating Emotion Through a Haptic Link

a study of the influence of metaphor, personal space and relationship

by

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B.Sc., The University of British Columbia, 2003

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

Master of Science

in

The Faculty of Graduate Studies

(Computer Science)

The University Of British Columbia

November, 2005

Abstract

The world is more and more connected and yet we are often physically distant from people we care about. Technology increasingly supports remote interpersonal communication but has yet to integrate our sense of touch into this interaction. Researchers in the field of haptics (touch and technology) have started exploring computer-mediated touch interaction. The question is how should a computer-mediated person-to-person touch interaction be designed.

In this thesis, we concentrate on how the design of a haptic interaction model influences performance and subjective experience of a dyad. Specifically, we examine the effect of using different metaphors to develop and explain the haptic interaction model, creating interaction models with and without a haptic display of personal space, and the type of relationship shared by the dyad using the device on ability to communicate emotion haptically. We also explore how dyads use these interactions to communicate emotion.

We ran a structured study, in which participants communicated emotion with a haptic device and found that participants were able to communicate some emotional content through the haptic interactions. A significant effect of the interaction metaphor on performance was found. Participants preferred interactions with a haptic indicator of personal space, and participants' reported metaphor preferences depended on their relationship. Finally, we found that common actions were used to express each emotion, even though this is a new media unfamiliar to participants.

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Acknowledgements

Wow, I finished my MSc thesis, with lots of help along the way. I would like to thank my supervisor Karon MacLean. Karon seemed to know when to let me wander and discover, and when to reign me in. She encouraged me to go to grad school and has been a mentor to me from the start. Also I would like to acknowledge the awesome influence that my flute teacher, Cathy Dochsteader, and my high school math teacher, Ms. Baird, have had on my life.

Thanks to Cristina Conati for being my second reader and attending my presentation. Thanks to Kellogg Booth and Michiel van de Panne for being on my thesis committee and to Joseph Luk for proof reading.

My family have always been there for me, and have been the sunshine in my life from the get go. Thanks Mom (Sheila Smith), and Dad (Ron Smith). My sister has always been my closest friend, and even helped pick apart my experiment ideas until I had one that made sense. Thanks Rachelle for being such a great sis!

I have been lucky to meet and befriend many magnificent people but would like to thanks here those who fed me and kept me sane during the past few months: Cecile Leung, Stacy Langsdale, Viann Chan and Micheal Lee, Mark Crowley and Lily Hue, Greg Kempe, Mike Klaas, and Warren Cheung. Thanks also to my labmates. Especially to Colin Swindells, and Mario Enriquez who have been friends and accomplices of mine for the past year and a half. Finally, I would like to acknowledge everyone in my grad class. Never before have I met such a fun, intelligent and interesting group of people.

Part I

Thesis

Chapter 1

Introduction

1.1 Motivation

In an increasingly connected world, we often find ourselves physically separated from those we care about. A plethora of electronic communication devices including the telephone, email, cell phones, instant messengers and blogs provide us with means of connecting with people who are not physically present with us. However, these devices do not enable us to use our sense of touch during remote interaction.

Touch is an important aspect of person-to-person communication in face-to-face situations. Research has shown that touch can have a profound effect on our mood and behaviour. Furthermore, touch plays an important role in establishing and maintaining intimate relationships [21].

For many years, researchers in computer science, engineering and psychology have been working to better understand our sense of touch and to build, evaluate and understand systems that allow us to interact with computers through our sense of touch. This field of study is known as haptics. The majority of haptics research has focused on interaction between one person and a computer. However, several research projects have started to look at using touch for computer mediated communication between multiple people. Some of these projects study the possible benefits of adding touch to existing interactions, while others create new touch interactions.

1.2 Objectives

The "computer" in computer mediated communication means that the interaction is no longer direct. Therefore, it is possible to design and create new interactions. Communications researchers tell us that people think of and use new media interactions as new communication channels with their own strengths and weaknesses, rather than as deficient face-to-face communication [17]. Given the flexibility to design computer mediated haptic (touch) interactions, and knowing that such interactions will be judged by their unique strengths and weaknesses, how should an interaction designer proceed? The challenge is to create a compelling interaction model.

In this thesis, we examine several aspects of a computer mediated dyadic (two person) haptic interaction, and try to assess their influence on the emotional expressiveness of the interaction and on the subjective experience of the pair engaged in the interaction. We explore three aspects of computer-mediated haptic interaction:

1. Metaphor used to design and explain the interaction
2. Presence or absence of a haptic display of interpersonal space
3. Relationship shared between the people in the dyad engaged in the interaction

1.3 Research Approach

Our approach to the problem of discerning essential affordances for emotionally communicative, mediated haptic interactions was to concentrate on the interaction model. Specifically, we used an existing one-degree-of-freedom device to allow us to concentrate on the interaction on the device rather than the form and function of the device itself. Moreover, we decided to concentrate on dyad interactions , which encompass many of our relationships and are technologically and socially easier to explore.

There are many ways to design a computer mediated haptic interaction for non co-located dyads. Our approach was to base our interactions on metaphors of haptic interaction engaged in by dyads who are co-located in the real world. We wanted to find out if the metaphor used to design and explain the interaction affected the ability of dyads to communicate emotion using the haptic device. We were also interested in the effect of the metaphor on the dyads' subjective experience.

During face-to-face interactions, people use personal space as part of their nonverbal communication. Before a dyad can engage in real-world touch interaction, they must be sufficiently close together. Since our metaphors are based on face-to-face interactions, we wondered what effect providing a haptic indicator of personal space would have on performance and subjective experience.

Finally, the relationship a dyad shares affects the kinds of touch interactions that are used to communicate. We wanted to see if this was also true for computer mediated haptic interactions.

To study these three aspects of computer-mediated haptic interaction (metaphor, space and relationship) we first designed several haptic interactions that varied according to metaphor and created a haptic indicator of personal space to add or remove from these interactions. The second phase of the research was to design and carry out an experiment to test whether metaphor, space and relationship had an effect on ability to communicate emotion or the subjective experience of the dyad using the interaction.

1.4 Thesis Structure

Throughout the remainder of this thesis we describe in more detail our research process, results and the implications of our findings. In Chapter 2, we present an overview of related work and its relevance to the current work. In Chapter 3, we discuss the design of the haptic interaction models that we created and in Chapter 4, we describe the experiment we designed to use these interaction models to test the impact of metaphor, spatial awareness and relationship on the interaction. In Chapter 5, we present the result of the experiment and in Chapter 6, discuss the meanings and implications of these results. Finally, in Chapter 7, we conclude with the contributions of this work and suggestions for future work.

Chapter 2

Related Work

This thesis examines the effect of the haptic interaction model and the relationship shared by a dyad on their performance and subjective experience when they are engaged in an emotion communication task through a computer-mediated haptic interaction. We briefly present the findings from the communications, psychology and sociology literature, which motivated and directed the current work. We then discuss the relevant work in the haptics literature, beginning with an overview of some of the major areas of haptics research, and followed by a discussion of research in the area of computer-mediated haptic communication.

2.1 Media

Steuer [37] encourages communications researchers to use the knowledge they have gained from studying existing media to make predictions about and facilitate the design of new media. Similarly, we can make use of some of this knowledge when we design and evaluate new media interactions. Communication events can be classified according to three factors: the nature of the audience, the relationship between sender(s) and receiver(s) and the medium used to communicate [17]. We can use a similar structure to define the types of communication for which we are interested in designing. In the current work, we are interested in dyad interaction without an audience and in seeing the effect of relationship on the interaction. The medium we are studying is a computer mediated haptic device but with various models of interaction.

New communication technologies can be compared to face-to-face communication or viewed as improvements to existing channels. However, users view new communication channels not as improvements on existing channels but rather as unique channels to be judged and used according to their own uses and characteristics [17]. Thus there is value not just in comparing communication technologies to face-to-face communication or to each other but also in studying the characteristics of a particular communication technology. Furthermore, since we are interested in the use of a computer mediated haptic communication device to communicate emotion, it is important to look particularly at its suitability for this use.

2.2 Co-located Communication

In their introduction to a compilation on nonverbal communication [39], Wiemann and Harrison make the following observation about nonverbal communication, "Non-language messages generated by movement, unlike their language counterpart, are unique in that they convey responsiveness on a moment-by-moment basis to the others present in face-to-face interaction." As technology strives to enable exchange of such real-time non-language messages, face-to-face communication often serves as a starting point. We look to the ways people use touch and personal space in face-to-face communication to inspire and direct the design of our haptic interaction models.

2.2.1 Touch

Hall and Knapp observe that "Touch is a crucial aspect of most human relationships. [21]"

Touch is the first sense to develop [25] and is unique among the senses in being reciprocal, with both sensing and actuation [14]. Touch can convey many meanings and the how or when of touch is largely based on culture and socialization [10]. Hostility, sexual interest, nurturance and dependence, affiliation [1] and the level of intimacy in a romantic relationship [10] are some of the social messages that can be conveyed through touch. How touch is interpreted depends on the situation and the perceived appropriateness of the touch for the situation [12]. For example, touch can raise anxiety in physically or emotionally distant situations and is positively perceived if it is deemed situationally appropriate and the level of intimacy is not higher than that desired by the recipient.

The meaning of a touch is influenced by many things: part of body touched or touching, length of touch, amount of pressure, movement after initial contact, the social situation including who is present, and the relationship of those involved in the touching event [18]. One specific example is that the comfort level of the recipient of a touch is related to the relative intimacy of the touch and the relationship between the two. We explore the use of touch in computer-mediated interaction, and specifically, intimacy of touch and relationship.

2.2.2 Personal Space

Interpersonal distance is one of the elements of personal expression that can only occur in the presence of another, unlike for example, facial expressions, which can be made by an individual alone. The aspects of communication that require the presence of two or more individuals are often used to express attitudes and intimacy [10].

Four levels of distance were experimentally defined by Hall [16]. These levels, in increasing order of distance, are intimate distance, personal distance, social distance and public distance. Many factors influence the distance at which an interaction occurs. These factors include sex, age, culture, topic, interaction setting, physical and personality characteristics, attitude and emotional orientation, and relationship [21].

Closer distances are used during discussion of a pleasant topic than during discussion of an unpleasant topic [21]. More intimate relationships result in closer distances, and encounters that occur at intimate distance can be very negative if they are not intimate [10]. In general, violations of expected use of personal distances carry messages [6].

This thesis examines whether the notion of personal space in a virtual haptic space can be utilized in emotional communication.

2.2.3 Emotion

There are two aspects of emotional expression: the physiological changes that occur simultaneously with the feeling of the emotion, and the intentional communication of an emotion [10]. Studying the intentional communication of cognitive emotion does not capture the full emotional experience but is a good first approximation [10]. In our experiment, we study intentional communication of cognitive emotion.

2.3 Haptics Overview

Researchers have been working on creating devices and algorithms to facilitate human computer interaction through haptics (our sense of touch). To date the majority of haptics research has focused on device design, control, rendering real world haptic sensations and the psychophysical properties of our sense of touch.

A wide range of haptic devices have been developed and used. One of the most well known is the PHANToM [24], which is a point-contact, stylus-based, 3-degree-of-freedom (3-DoF), force feedback device and was the first commercial haptic device. A point-contact force feedback device that operates in a plane (2DoF) is the Pantograph [32]. A more recent device in this category is a low cost 1DoF device designed for teaching students system dynamics and embedded control [15]. Other force feedback devices range from elaborate exoskeletons, for example [3], to one degree of freedom force feedback knobs, for example [23].

Some examples of non-force feedback devices include passive haptic devices and tactile devices. An example of a passive haptic device is the Tango [30], which is a physical, deformable object that senses how a user is holding and manipulating it. Several different types of devices have been designed to display tactile information including STRESS [31], which uses lateral skin stretch to give the illusion of vertical deformation.

A greater understanding of the human haptic (touch) sense facilitates the design of devices, renderings and interactions that communicate information to humans more appropriately and effectively. Haptics researchers have been exploring technology and the human haptic sense to further our knowledge about what types of haptic signals and changes in haptic signals humans can detect. This includes investigations into aspects of human perception such as the degree of pressure change required for objects of varying surface areas before the change is detectable to human subjects, and joint angle resolution[38], and the effect of spatial and temporal differences between two vibrotactile taps on the perception of the physical distance between the two taps [9]. Sensitivity to temperature changes in materials with high thermal conductivity is an example of investigations into human perception of temperature[19]. MacLean and Enriquez [22] examined vibrotactile signals of varying frequency, amplitude and wave shape and found that people mapped these signals to a two dimensional perceptual space.

The effect of visual or auditory stimuli on haptic perception have also been explored: visual and audio cues have been shown to alter perceived haptic properties. A study involving different visual renderings of a physical spring, as participants compressed it, found that the visual representation affected the perceived stiffness of the spring [36]. Sound has also been shown to influence perceived stiffness, though the effect was found not to be as strong as the effect of visual cues [11].

In summary, haptics researchers have been exploring everything related to touch and technology from device design to human haptic perception. We are interested in exploring how this haptic technology can be used to facilitate computer mediated person-to-person haptic interaction.

2.4 Computer Mediated Person-to-Person Haptic Interactions

Recently, more projects are being done to begin to examine person-to-person computer mediated haptic interaction. This research has introduced the idea of connecting people remotely through touch, looked at device design for dyad haptic games, and employed haptics in collaborative tasks. In this section, we discuss the research in computer mediated person-to-person haptic interaction.

Motivated by the lack of touch interaction in remote communication, Brave and Dahley designed inTouch [4] [5]. The device consists of two sets of three rollers and communication is established through the sense of interacting with a shared object that is created by both sets of rollers moving as if both users are acting upon them. During informal user feedback, some users thought the inability to convey concrete information would be a problem while others thought this was the strength of the interaction. Users suggested that this device would be most suited for intimate relationships; however, this was not systematically studied. In our research, we take some of the ideas from this work and do a more systematic, structured evaluation of the interaction and experience of the dyad using such a haptic device. This includes looking at the effect of relationship on the interaction and experience.

Another device built for interpersonal interaction is HandJive [13]. The focus of this work was on designing a device for a purely haptic two player game in an environment where audio is inappropriate. The individuals involved in the interaction are co-located but not necessarily in view of one another. HandJive uses two orthogonal axes so that each person controls the horizontal position of their own device, which translate into the vertical position of their partners device. Several possible games and a possible haptic language are described by the designers of HandJive. The focus of HandJive was on device design and play; whereas, we focus on the design of the haptic interaction model and communicating emotion.

The "Hug Over a Distance" is a device designed to support unobtrusive, haptic interaction between intimate couples [26]. The prototype device consisted of a vest with air pockets for receiving a virtual hug and a koala to rub to send a virtual hug. The device was presented to users in a workshop format. Users were unable to de-couple the sound of the air compressor used to inflate the pockets from the interaction, and did not feel that they would use it in their daily lives. However, it stimulated discussion of ideas for new interaction devices.

A framework facilitating the use of haptic icons in the context of instant messaging is presented in Haptic IM [33]. The authors discuss the idea that hapticons (iconic haptic signals) could be used as a form of non-verbal communication cues in the instant messaging context.

There have been several projects that examine whether the presence/absence of haptics in a virtual environment affects task performance or the sense of interacting with another individual in a collaborative task performed with users located remote from each other. In one study, two people worked together to hold and move a virtual ring along a virtual wire without bumping into it [2]. The interaction was through two PHANToMs and two monitors connected to the same computer. A visual-only and a visual-plus-haptic condition were used. One of the two users was always the same "expert" user. The results showed slightly increased performance and sense of presence of the other in the visual-plus-haptic condition. Sallnas et al. [35] conducted another study showing similar results involving a visual + audio condition and a visual + audio + active haptics condition. The task involved using a PHANToM to move blocks around in a virtual space. Task performance and sense of presence were somewhat higher with the active haptics. Transatlantic touch [20] is another similar study were two participants collaborated to lift a cube. In this study, participants were on opposite sides of the Atlantic. An increase in sense of presence with haptics was again reported. We are interested in examining interaction when only haptics is available for a communication task.

Non-colocated collaborative application environments are often seen as lacking awareness and cues provided by nonverbal communication in face-to-face situations. In a collaborative editing environment, in which each user has their own cursor, haptics have been proposed as a way to try and increase awareness of where the other editor is in the environment [29]. In this paper, several haptic interactions between cursor "avatars" are discussed. An observational evaluation in which pairs of users created UML diagrams in either a visual + audio or a visual + audio + haptic condition found that some users did make use of the haptic interactions when they were present and that there was high variability among participants in the use of the haptic interactions. One of the haptic interactions between the two cursors is a resistance to movement of the workspace or a small vibration when one approaches the other. The goal of these haptic cues is to provide a haptic proximity sense. In this thesis, we look specifically at how the presence of a haptic proximity sense influences haptic interaction during an emotion communication task.

In a collaborative editing environment, in which there is only one cursor that users share, haptic signals have been purposed as a way to provide a non-verbal mechanism for turn taking [7]. An initial study, in which groups of four had to arrange furniture on a map according to difficult constraints, suggests that more equitable turn-taking may occur with a haptic mechanism than with only a visual mechanism. Overall, participants in the study preferred to have access to both the haptic and visual mechanisms. ComTouch [8] examines the use of a simple bidirectional haptic signal combined with audio, in dyad communication. The idea of a haptic device that allows users to send messages through pressure and receive them as a vibrotactile stimulus coupled with the audio channel was tested through two experiment tasks. The first task was to use the device while having a conversation with no view of the other. The second task required cooperation in a survival game with use of the audio channel discouraged. In the conversation task, participants used the device for emphasis, mimicry and turn-taking. They were not always aware of having used it in these ways. The results of this research suggest that there is potential for haptic signals to play some of the roles in remote communication that nonverbal cues provide in face-to-face interaction. We explore the use of haptics in emotional communication.

To show the benefit of haptic interactions, many studies compare them to visual-only and/or visual and audio-only interactions. Our approach is to consider haptic-only interactions to be a unique, and potentially useful medium worth studying in their own right. We are interested in exploring how a haptics-only device is used in remote computer-mediated interpersonal emotional communication. Adding vision and/or audio creates a different interaction medium, and we are interested in concentrating on how different haptic interaction models affect the communication rather than on different modalities.

Chapter 3

Interaction Design

In this thesis, we examine how the haptic interaction model and the relationship shared by users affects interaction between dyads given the task of communicating emotion through a haptic model. We look at three different aspects of the interaction: intimacy of the relationship between the dyad, the metaphor used to develop and explain the haptic interaction, and whether a haptic indicator of personal space is present in the virtual haptic interaction. In this chapter, we describe the design of our interaction models and choice of relationship types. These models were designed to be used in an experiment (described in the next chapter) that manipulates metaphor, support of interpersonal spatial awareness and relationship, and measures impact on performance and subjective experience, during an emotion communication task with a haptic device.

In this chapter, we first discuss the role of visual representations in explaining our haptic interaction models. Next we briefly describe several interaction metaphors that we developed. We then discuss our rationale for choosing two of these metaphors for our experiment, and the implementation details of these two models. Next we present the haptic signals we designed to act as indicators of personal space, and the pilot studies we did to choose an indicator that people could use. Then we discuss the role of relationship in the interaction. Finally, we summarize the interaction models and relationship factors that we used for the experiment.

3.1 Role of Visual Representations

Our interaction models are designed and explained using metaphor, and this strategy makes it easier to explain the force mapping between the haptic input and output. It is not possible for a user to feel how his actions affect the output his partner feels. Thus, to help users develop a mental model of the interaction, we also develop simple visual representations of the interaction models. Being able to see what the other is doing helps a user to map the haptic stimuli they feel to their own and their partners' actions. These visual representation are designed to explain the haptic mapping and are not used during the experimental trials.

3.2 Metaphors

Initially we defined four levels of haptic metaphor intimacy that we were interested in studying(Figure 3.1). The least intimate interaction between two people involving touch is through a shared object that is touched by one person at a time, for example a soccer or ping pong ball. The next level of intimacy is through a shared object that is manipulated by both people at the same time, for example a table being carried, a tug-of-war rope or a two person crosscut saw. The more intimate levels involve direct touch. Less intimate direct touch includes shaking hands or patting on the shoulder. More intimate direct touch includes massaging, stroking and holding hands [18]. Using this intimacy scale, we developed four interactions based on four touch metaphors that span it: playing Ping Pong, cutting down a tree with a crosscut saw, shaking hands and holding hands.

Ping Pong The Ping Pong interaction metaphor is of two people playing a game with a ball and two paddles. The haptic knobs become the paddles and the motion of a virtual ball determines the force on the paddles. Each person

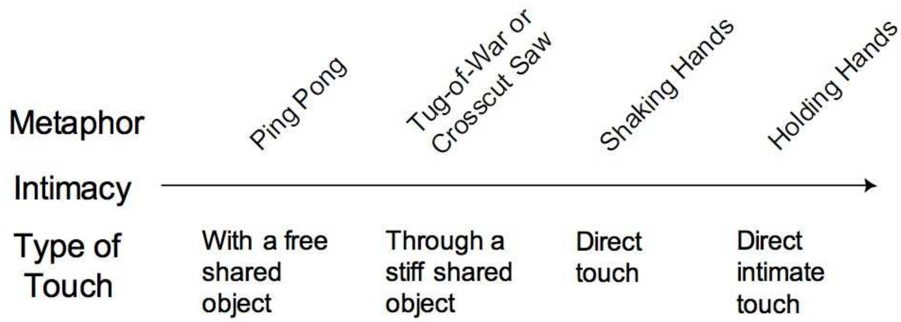

Figure 3.1: Scale of Intimacy of Haptic Interaction

controls the horizontal position of a Ping Pong paddle and a ball moves back and forth between the paddles. Hitting the ball speeds it up and cradling it slows it down. A virtual net separates the two players. A player running into the net feels a strong force as if hitting a wall.

Crosscut Saw The crosscut saw interaction models a situation where two people interact simultaneously with a shared object. The interaction metaphor is that of cutting down a tree using a large two person crosscut saw. The force feedback depends on the current user actions as well as the mode.

There are three basic modes:

1. The saw is on the ground

2. The saw is being held/manipulated by both people

3. The saw is being picked up or put down. This third mode actually includes multiple states involving all combinations of one or more of the people picking up or putting down the saw.

When both people are holding the saw, they feel the motion of the other through the saw. If they move the saw in front of a virtual tree and move in the same direction together, then they saw the virtual tree. A rough vibration is felt when sawing. After sufficient sawing, the tree falls and a violent vibration is displayed on the knob as if one is feeling the ground shake as the tree hit it.

Shaking hands In this interaction, the metaphor of shaking hands is used. There are three modes during the interaction.

1. The approach. The hands are not in contact.

2. The contact. The initial contact stage. The initial contact will be influenced by the approach.

3. The shake. This is the actual handshake. A connection is modeled between the two hands.

The position of each motor is mapped to the motion of the hand. When the hands are apart(approach stage), then the motor position represents the horizontal position of that hand in the space; thus moving the motor towards of the other will bring the corresponding hand closer to its partner. When the hands are in contact(shake stage), then motor position is mapped to the rotational position of the hand; moving the motor side-to-side then corresponds to shaking the hand up and down.

Hand Stroke This interaction started out based on an interlocked handhold, with attraction points corresponding to when two hands are positioned with fingers intertwined. Moving between these points would feel like sliding across a surface with friction. People using just the sliding across mode of this interaction found it compelling and we decided to simplify the interaction by dropping the intertwined mode, because it seemed to break up the connect that people felt with the sliding action. Furthermore, stroking is the most intimate form of face-to-face touch [27], and thus the metaphor of two hands stroking is a more intimate metaphor than that of two hands holding each other.

3.2.1 Metaphors for the User Study

After designing these four interactions, we decided to concentrate on the Ping Pong and Hand Stroke interactions for our user study (described in the next chapter). We decided to use only two interactions because we expected there might be considerable variation among users, and thus wanted a within subjects design for the metaphor factor. It was not realistic to test more than two metaphors in a single session: using two metaphors allowed sufficient time for training, an appropriate number of trials for each condition and for participants to answer questions about their interaction experience, during a two-hour session.

The Ping Pong and Hand Stroke metaphors were chosen for several reasons. The primary reason was their location at opposites ends of our intimacy scale, thus providing the greatest difference in intimacy. Another reason was because the relatively straightforward mapping from the metaphor to the interaction model allowed users to quickly understand the haptic model through the metaphor. The crosscut saw and handshake metaphors both involved several modes, and it was not always clear to pilot subjects which mode they were in. It may be possible to create haptic signals that would provide a better indication of mode, but we did not find a way to do this without creating more complex interaction models , which could make it more difficult for users to understand the mapping between the haptic metaphor and the haptic interaction. Another option would have been to simplify the crosscut saw and handshake interactions; for example, by restricting users to always hold the saw in the crosscut model. However, we felt this might create interactions that were too close to being simple push/pull interactions, which Fogg et Al found led users to fight for control [13].

3.2.2 Implementation Details

In the following sections, we describe the haptic and visual implementation of the two interaction models that we chose to develop further and use for our user study.

Ping Pong Implementation This haptic interaction is based on a physical rendering of a model of a ball in a horizontal plane. The ball has a mass and an initial velocity. When it is not in contact with either paddle it continues moving in the space with only a little friction applied to its motion. The paddle is modelled as a spring with an anchor point that moves with the user's knob. The spring constant determines how quickly the ball changes direction. Moving the paddle after the ball has come in contact with it changes the position of the spring and thus influences how fast the ball leaves the paddle. For example,"swinging" your "paddle" towards the other player, after the ball has contacted, it sends the ball faster in their direction. A faster ball will hit a paddle with a greater force. In the middle of the virtual space, separating the two players is a net, which is modelled as a wall. If a user crosses the net, then a constant force will push them back towards their side of the net.

The visual representation of the Ping Pong interaction(Figure 3.2) consists of two rectangles whose positions correspond to the position of the paddles as determined by the positions of the two knobs. In the middle of the screen, a line representing the net divides the space. A circle representing the ball moves back and forth across the screen as the ball moves around in the space.

The force on the ball is used to update the ball position. When the ball is moving through the space between the paddles, only a small amount of force "friction" is applied to the motion of the ball slowing it down. If the ball is in contact with a paddle, the force on the ball is determine by how far "into" the paddle the ball has travelled(Equation 3.1). The paddle is modelled as a point with a small spring attached. The ball makes contact with the paddle by

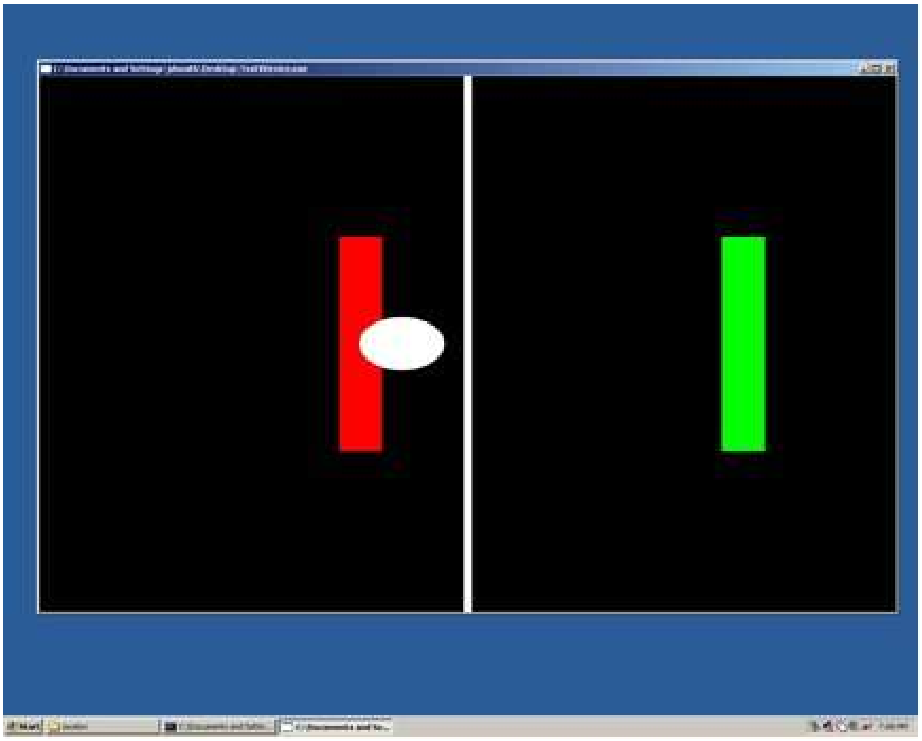

Figure 3.2: Screen shot of visual representation of Ping Pong metaphor

hitting the spring and leaves the paddle when it leave contact with the spring at rest position.

$$f_b = \begin{cases} -b\dot{x}_b & \text{if } x_b < x_{p1} \text{ and } x_b > x_{p2}, \\ k((x_{p1} - l) - x_b) - b\dot{x}_b & \text{if } x_b > x_{p1} - l, \\ k((x_{p2} + l) - x_b) - b\dot{x}_b & \text{if } x_b < x_{p2} + l. \end{cases} \quad (3.1)$$

f_b is the force on the ball

x_{pi} is the position of the paddle i

x_b is the position of the ball

$\dot{x}_b$ is the current velocity of the ball

$\ddot{x}_b$ is the current acceleration of the ball

k is the spring constant

l is the spring length

b is the damping constant

The force on the ball is used to update the ball's acceleration ($\ddot{x}_b$), velocity ($\dot{x}_b$) and position (x_b) during the ith time step of duration T.

$$\ddot{x}_{b_i} = f_{b_i}/m_b \tag{3.2}$$

$$\dot{x}_{b_i} = \ddot{x}_{b_i}T + \dot{x}_{b_{i-1}} \tag{3.3}$$

$$x_b = \dot{x}_{b_i}T + x_{i-1} \tag{3.4}$$

Thus, if the ball is in contact with a paddle during a given time step, then there is a force on the corresponding knob. This force is the opposite of the force applied to the ball plus a small constant, Equation 3.5. The constant is used to ensure that a slow moving ball will still be felt when it comes into contact with the paddle. In addition, if the paddle has moved into/across the net, then a strong force will push the paddle back towards its side of the net.

$$f_{p1} = \begin{cases} -f_b + c & \text{if } x_b > x_{p1} - l \text{ and } x_{p1} > p_w, \\ -f_b + c + w & \text{if } x_b > x_{p1} - l \text{ and } x_{p1} < p_w, \\ 0 & \text{if } x_b < x_{p1} - l \text{ and } x_{p1} > p_w, \\ w & \text{if } x_b < x_{p1} - l \text{ and } x_{p1} < p_w. \end{cases} \tag{3.5}$$

$$f_{p2} = \begin{cases} -f_b + c & \text{if } x_b < x_{p2} + l \text{ and } x_{p2} < p_w, \\ -f_b + c + w & \text{if } x_b < x_{p2} + l \text{ and } x_{p2} > p_w, \\ 0 & \text{if } x_b > x_{p2} + l \text{ and } x_{p2} < p_w, \\ w & \text{if } x_b > x_{p2} + l \text{ and } x_{p2} > p_w. \end{cases} \tag{3.6}$$

c is a small constant added so that a slow moving ball will still be felt

w is the net constant

p_w is the position of the net

Hand Stroke Implementation If the virtual hands are in contact then the force felt on the knobs is determined by the relative velocity of the knobs and the area of the virtual hands that is overlapping. Metaphorically, slow movements are like the two hands being pushed more against each other and fast movements are like the hands gently and quickly brushing across each other.

The visual representation of the Hand Stroke interaction consisted of two rectangles whose position corresponds to the position of the hands in the space as determined by the position of the paddles(Figure 3.3).

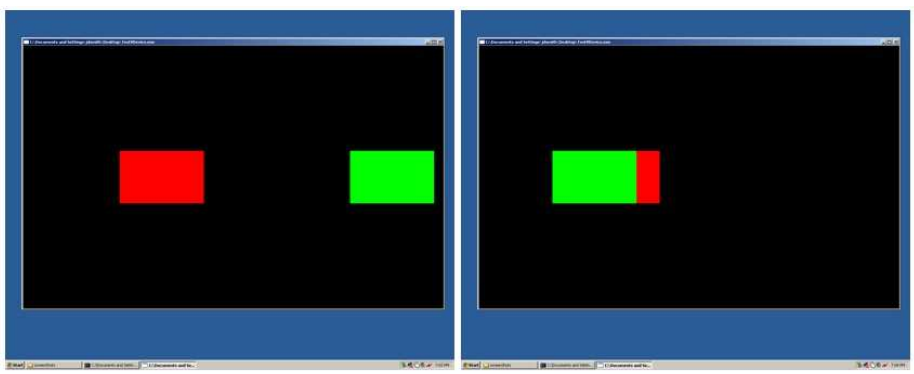

Figure 3.3: Screen shot of visual representation of the Hand Stroke metaphor; (a) “hands” not in contact, (b) “hands” in contact

Figure 3.4 and Equation 3.7 shows how the force varies according to the relative velocity of the haptic knobs. To increase the richness of the interaction model at slower velocities a strong force is used at low to medium relative velocities. As the relative velocity becomes high, the amount of force gradually decreases. Also as the area of contact decreases, the force decreases.

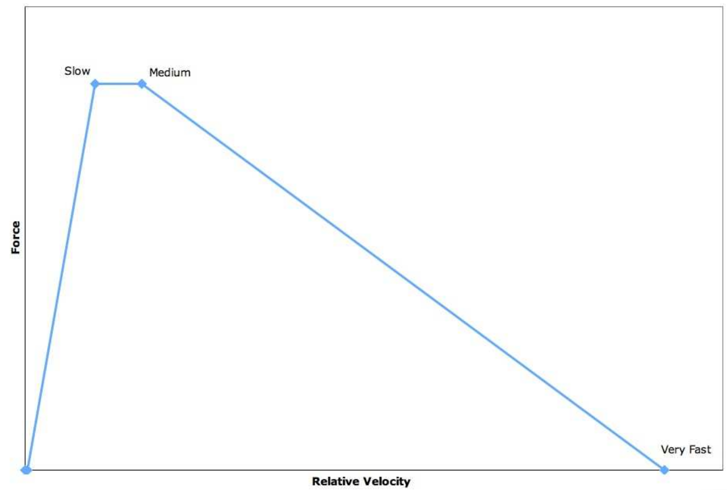

Figure 3.4: Hand Stroke metaphor: mapping between relative velocity and force

$$f_{k_1} = \begin{cases} s_1\dot{x} & \text{if } \dot{x} < \text{Slow Velocity,} \\ f_{big} & \text{if Slow Velocity} < \dot{x} < \text{Medium Velocity,} \\ f_{big} - s_2\dot{x} & \text{if Medium Velocity} < \dot{x} < \text{Very Fast Velocity.} \end{cases} \tag{3.7}$$

f_{k_1} = the force based on the relative velocities of the two knobs

$\dot{x}$ = the relative velocity of the knobs

f_{big} = a constant force of large magnitude

s_1 = slope up determined to make a smooth transition to f_{big}

s_2 = slope down determined to make a continuous transition from f_{big} to f_{small}

The area of the contact between the hands also affects the force. As the area of contact decreases, so does the force, Equation 3.8.

$$f_{k_2} = \begin{cases} f_{k_1} - c * y^2 & \text{if } c * y^2 < f_{k_1} \text{ and } y < k, \\ 0 & \text{if } c * y^2 > f_{k_1} \text{ or } y > k. \end{cases} \tag{3.8}$$

f_{k_2} = the force output to the knobs

c = a constant

y = relative distance between the virtual hands (0 = directly on top of one another)

k = distance apart at which the hands are no longer touching

3.3 Personal Space Indicator

The models we created are based on metaphors of real world touch interactions that involve a physical space. With these models we create a virtual interaction space. The basic models make use of distance in this interaction space but do not explicitly give users any indication of the position of their partner relative to their own position in the virtual space. Since the visual representations were only used for training, everything including distance in the virtual space had to be perceived through haptics.

During face-to-face interactions, peoples' use of personal space correlates with the intimacy of the interaction and emotional orientation, among other things [21]. Furthermore, when using our preliminary interaction models with both the visual and haptic representation present, people seemed to make use of the concept of relative distance that the visual provided. Thus, we were interested to see if a haptic display of personal space would affect either how well emotion could be communicated or the interaction experience of users, when there is no graphical feedback present.

We decided to use two values for the factor haptic personal space indicator: haptic display of personal space present or absent. This required first designing a haptic means of signalling relative distance between two people in the virtual space. We decided to use a haptic vibration modulated by distance to indicate interpersonal distance and thus developed several possible haptic vibrations to indicate how far apart the two people involved in a haptic interaction were from each other in the virtual space. We did two pilot studies to test these candidate vibrations and to identify the one that people could best use for a sense of distance in the virtual space.

3.3.1 Initial Spatial Stimuli - Vibrations and Evaluation

In a pilot study with four subjects, we tested four haptic vibrations for indicating interpersonal distance in a haptic space. These test were done in a virtual haptic space that did not contain any other signals, but these vibrations were all designed to be subtle so that they would not overpower the interaction models that we would later add them to.

Vibrations We created four haptic vibrations that depended on the spatial distance between two objects in the virtual space. All were sin waves that were continuously displayed and the distance affected the amplitude and/or frequency of the wave.

1. Frequency increases linearly with distance
2. Amplitude decreases and Frequency increases with distance
3. Amplitude decreases with distance
4. Amplitude decreases quadratically with distance.

Experiment Task In this study, the subjects held on to the haptic knob as a haptic vibration was displayed according to the vibration being modelled and the position of a simulated second person moving towards or away from them in the space. For each trial, subjects were asked to indicate, with the mouse, where in the space (along a horizontal axis) they thought the other had started and stopped and to indicate, by selecting a labelled key, what speed they thought the other was moving at: slow, medium, fast. Subjects were not told the mappings as we hoped that one or more of our mappings might be intuitive to the subjects.

Subjects Four subjects did 20 trials for each of the four conditions. The subjects were all computer science students: three males, one female. The subjects were all 20-29 years old.

Results and Discussion Overall, subjects were not able to determine the absolute or relative start, or end positions and the results were almost exactly what would be expected if subjects were picking positons and speeds at random. Furthermore, there was no pattern to suggest that subjects had understood our vibrations but mapped them in the reverse direction, for example mapping an increase in amplitude to greater rather than smaller distance. The only exception to these random results was with the vibration with amplitude decreasing with greater distance. In this condition, one subject was able to determine direction (i.e. selected end position was on the correct side of the selected start position) in 90% of the trials.

Discussions with subjects revealed that they were unable to successfully make a mapping of what was going on. Furthermore, when asked about the mappings every subject seemed to have been looking for something different. The various models that subjects were looking for or formed during the experiment were quite varied. These models included a model similar to that of a race car approaching and receding, a mapping of intensity to velocity and length to distance, acceleration, and a step function. Several subjects seemed to assume that there were separate indicators of distance and speed. This may be an artifact of the tasks that subjects were asked to do which involved separately locating the starting and ending locations of a simulated other and indicating the speed, or it may suggest that is appropriate to separate the velocity and position cues.

Implications The results of this preliminary study led to two conclusions. First, there does not appear to be a common intuitive mapping that subjects were expecting. It is possible that there is a haptic signal that intuitively maps to distance but we did not find it either among the four we developed or by asking subjects directly what they would expect as a haptic signal to indicate distance. This suggests that some initial training to help subjects understand our vibration mappings is necessary. Given that several subjects seemed to be assume that there were separate indicators of distance and speed, we may want to try haptic vibrations that separate the velocity and position cues.

3.3.2 Final Spatial Stimuli - Vibrations and Evaluation

After our experience with the first study we designed and ran a second small study to evaluate potential haptic indicators of spatial awareness. Some changes were made to the stimuli as well as to the study design.

Vibrations Three of the stimuli used were based on the comments from the subjects in the first study, one with discretized intervals, one with separate velocity and position cues, and one with separate velocity and position cues and discretized distance intervals. We tried the discrete intervals because one subject in the first pilot had indicated that he was looking for a step function. The fourth stimulus was the most promising from the first study.

1. sin frequency decreases at discrete intervals with distance
2. sin frequency increases with velocity of partner and amplitude decreases linearly with distance
3. sin frequency decreases at discrete intervals with distance and amplitude increases with relative velocity
4. sin amplitude decreases linearly with distance

Experiment Task Similarly, to the first pilot the subjects held on to the haptic knob as a haptic vibration was displayed according to the vibration being modelled and the position of a simulated second person moving towards or away from them in the space. For each trial, subjects were asked to indicate, by selecting a labelled key, where in the space (near, mid-distance, far - along a horizontal axis) they thought the other had started and stopped and to indicate, by selecting a labelled key, what speed they thought the other was moving at: slow, medium, fast. This time there were five training trials for each condition during which the subjects saw a visual representation of the other moving towards or away from them in the space at the same time as the haptic stimulus was played. For each condition, after the five training trials with the graphic representation on, there were 20 test trials during which only the haptic stimulus was played.

Results and Discussion The results of this study showed that after training, subjects were able to reliably use the two haptic vibrations where amplitude depended on distance, vibrations (2) and (4), to determine speed, direction, start and end position(see Table 3.1).

	(1)	(2)	(3)	(4)	chance
speed	51%	74%	50%	73%	33%
direction	89%	85%	80%	90%	50%
start position	75%	75%	59%	80%	33%
end position	66%	78%	56%	79%	33%

Table 3.1: The mean percentage of correct trials for each space vibration condition.

Implications With training, subjects were able to understand and use the space indicators where the amplitude varied according to distance. We decided to use the vibration with only the amplitude varying (4) to indicate space in our metaphor implementations. Overall, subjects were the most accurate using this model, and also it is simpler than the vibration with both the amplitude and frequency varying.

3.4 Relationship

In the social sciences and communication literature, it is recognized that the relationship between individuals is an important part of what defines a communication event [17]. In particular, relationship influences touch protocols and the meanings associated with a touch. The gender of those involved in interpersonal touch is also found to influence how the touch is interpreted and received. Anecdotal reports suggest that the same may be true of computer-mediated touch. One of the first computer-mediated person-to-person touch interactions involved two sets of rollers. Each user moved a hand across her set of rollers and felt the motion of her partner through the motion of the rollers. When people interacted with the device, they thought that it would be most appropriate for intimate relationships [4] and not as appropriate for less intimate relationships. This preference suggests that relationship may influence appropriateness of computer-mediated haptic interaction models as it does in face-to-face touch interactions.

To begin a more structured investigation of the effect of relationship on computer-mediated touch interaction, we varied the relationship of those interacting. We wanted dyads whose relationship to each other varied in intimacy. Therefore, we chose to use dyads who were either strangers or who were romantic partners. The intimacy levels of these dyads are distinctly different and thus we believe that their interactions are most likely to show relationship differences. In all cases, the pairs were cross gender - one male, one female - in order to avoid any differences in same/opposite gender interactions.

3.5 Summary

In this chapter, we described the design of the values of the factors we developed for our user study. These factors are the metaphor used to design and explain the haptic interaction model, a haptic display of interpersonal space, and the relationship of the users.

The metaphors we considered for our user study ranged from game-like interactions to very intimate interpersonal touch interactions. We chose the interaction models based on the least intimate metaphor (Ping Pong) and the most intimate metaphor (Hand Stroke). We designed several haptic displays of interpersonal space and based on the results of pilot studies chose a sin wave with amplitude varying according to distance. In our study, half the interaction models (one with each metaphor model) had this interpersonal space indicator and the other half (one with each metaphor model) do not. We chose two relationship types (strangers and couples) based on the difference in intimacy of these relationship types.

Chapter 4

Emotion Communication Study

4.1 Objective

The objective of this study was to examine the effect of the design of an interaction model on computer mediated communication through a haptic link. In particular, we were interested in the effect of the interaction design on peoples' ability to intentionally communicate cognitive emotion using the device, their patterns of communication and subjective experience of the interaction. Since our focus was on the design of the virtual interaction model rather than on the device itself, a simple pre-existing device was used.

This study also looked at the effects of the relationship between the people using the device on their ability to communicate emotion, communication patterns and subjective experience using the haptic device. We looked at the effect of relationship because we believe that the relationship between users will influence how the interaction model for such devices should be designed.

The haptic interaction model, in the context of computer-mediated-person-to-person haptic interaction, is how the computer maps the input by the users into the haptic devices to device output to those users. It should be noted that both users provide input and receive output forces. This mapping is entirely up to the interaction designer and may range from a direct linking of force feedback devices to a complex function based on the state of both devices in the past and present.

There were three controlled experimental factors in our study design: two relating to the interaction model and one relating to the participants.

1. Interaction Model Metaphor - 2 levels

2. Haptic Display of Interpersonal Space - 2 levels

3. Relationship of Pairs - 2 levels

The first factor is the metaphor used to design the interaction model. Two metaphors suggesting different levels of touch intimacy were used: a game metaphor (Ping Pong) and an intimate touch metaphor (Hand Stroke). The interpersonal space factor had two values: a haptic indication of interpersonal space in the virtual space and no haptic indication of interpersonal space. The levels of relationship were stranger pairs and romantic couple pairs. These three factors are described in detail in previous chapter (Chapter 3).

This study looked at intentional communication of cognitive emotion. Specifically, in this study users were asked to convey various emotions using the haptic interactions but there was no attempt to make the users feel the emotion that they were conveying. Since users were intentionally conveying emotions that they were not feeling, the methods they used to convey emotion were a cognitive approximation of how they might convey actual felt emotion. Thus our results do not say anything about how well felt emotion could be communicated without intentional action; however, Collier suggests that looking at emotions as being intentionally conveyed is a good starting point for examining emotional communication [10].

4.2 Hypotheses

In this section, we present three sets of hypotheses that we had about the results of this experiment. The first set had to do with the effect of our primary factors on performance. The second set had to do with interaction between these factors. The third set had to do with the reported subjective experience of the participants.

4.2.1 Factors and Performance

Our primary hypotheses had to do with the ability to convey emotion in the different conditions:

1. Metaphor: The metaphor used influences the ability of pairs to communicate emotion through a virtual haptic space. Specifically, pairs would be able to successfully communicate emotion in more trials with the hand stroke metaphor will than with the ping pong metaphor.

2. Space: The level of haptic support for awareness of interpersonal distance influences the ability of pairs to communicate emotion. Specifically, pairs would be able to successfully communicate emotion in more trials with a haptic indicator of personal space than without a haptic indicator of personal space.

3. Relationship: The type of relationship the pair shares influences their ability to communicate emotion. Specifically, romantic partners would be successful at communicating emotion in a greater number of trials than strangers.

We hypothesized that pairs would be more successful at communicating emotion with the more intimate metaphor because it involves direct touch in the virtual space. Thus we thought it would be easier for users to control and understand how their actions affected what their partner felt.

We hypothesized that pairs would be more successful at communicating emotion with a haptic indicator of personal space because it would give them more ways to differentiate the emotions. We also thought that it would possibly enable people to bring spatial methods used in face-to-face communication into the virtual haptic space.

Finally, we hypothesized that couples would be more successful at communicating emotion through a haptic device than strangers since they have more knowledge of their partner's communication patterns. We believed that couples would be able to use their knowledge of how their partner communicates emotion face-to-face and through other media to understand their partner's strategies in this new media.

4.2.2 Interaction between Factors and Performance

We had one hypothesis about interactions between factors.

1. There will be an interaction between relationship and metaphor. Specifically, there will be a stronger effect for metaphor for romantic partners then for strangers.

It was our hypothesis that couple would be more comfortable with the Hand Stroke metaphor and so would be better able to make use of this metaphor.

4.2.3 Subjective Experience

The final set of hypotheses involved the participants' self reported subjective experience of the interactions.

Participants were asked which interaction they preferred, felt most connected to their partner through, felt most comfortable with, found the easiest to use to convey emotion and found the easiest to use to perceive emotion. For each of these questions we had the following hypotheses about which interaction users would choose.

1. Romantic partners would choose the more intimate metaphor, hand stroke.
2. Strangers would choose the more game-like metaphor, ping pong.
3. Both romantic partners and strangers would choose interactions with a haptic indicator of space.

We made the hypotheses about metaphor because we thought the more game-like metaphor was more appropriate for interaction between strangers and the more intimate metaphor was more appropriate for interaction within a couple. We made the hypothesis that everyone would select interaction models with a haptic indicator of space because it would provide them with a better sense of their partners intentions.

4.3 Metrics

The hypotheses about performance were tested based on the number of trials in which pairs successfully communicated emotion in each condition. The hypotheses about subjective experience were tested based on participants' answers to a questionnaire given at the end of the experiment (Appendix C).

4.4 Design

In this study, we used a mixed design to test our hypotheses. To test the hypotheses about the effect of metaphor and personal space on ability to communicate emotion, a within-subjects design was used. Each pair of subjects used each metaphor and space combination. Thus each pair used four interaction conditions. Since the relationship between the individuals in each dyad is predetermined, the hypotheses relating to relationship where tested between subjects.

A Balanced Latin Squares design (Table 4.1) was used to limit order effects while using a manageable number of subjects.

Ordering				
1	Ping Pong, No space	Ping Pong, Space	Hand Stroke, No Space	Hand Stroke, Space
2	Ping Pong Space	Hand Stroke Space	Ping Pong No Space	Hand Stroke No Space
3	Hand Stroke Space	Hand Stroke No Space	Ping Pong Space	Ping Pong No Space
4	Hand Stroke No Space	Ping Pong No Space	Hand Stroke Space	Ping Pong Space

Table 4.1: Condition Orderings: The four orderings used in our balanced Latin square design. Each ordering was used for two stranger pairs and two romantic partners pairs

4.4.1 Physical Setup

During the experiment the two subjects were located in the same room; however, they were unable to see each other or interact physically(Figures 4.1, 4.3). This was achieved by using a physical partition.

Each subject had a haptic device, Figure 4.2, with which they interacted. The two subjects were able to see the same monitor. This monitor was used during training and to give directions during the experiment. The monitor was used to communicate procedural information the experiment trials, but no metaphor or model information.

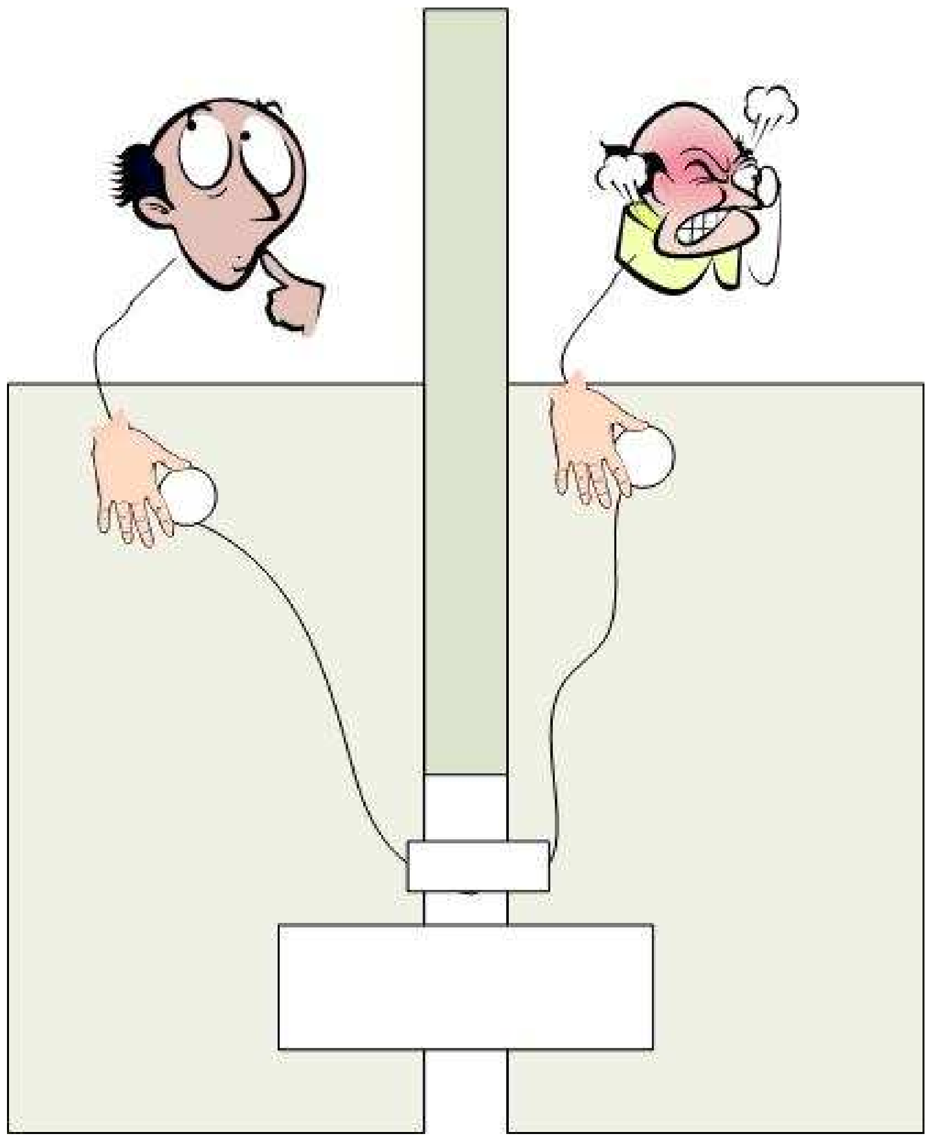

Figure 4.1: The participants sat on either side of a partition and communicated emotion through a haptic device.

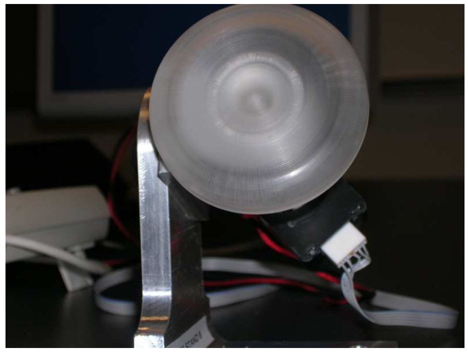

Figure 4.2: Each participant interacted through a haptic knob like this one.

Figure 4.3: A picture of two users using a haptic interaction model in our experiment set up.

4.4.2 Equipment

The haptic devices used in this experiment were two single degree of freedom force feedback devices (one for each member of the pair). The input to the computer from the motors is the motor position. The output from the computer to the motors was a voltage, which was conveyed as a force. The motors used were Maxon RE 025s with 1024 count/revolution optical encoders, HEDM-5500. Each motor is configured in direct drive and has a circular polycarbonate handle connected to its shaft.

A single computer running Windows XP was used to run the haptic interactions. The target update rate was 2kHz; however, since Windows XP is not a realtime operating system there was some variation in the signal update rate. For these interactions the noise introduced by this variation was not a problem.

4.4.3 Protocol

In this section, the experiment protocol is described.

Participants were taken into the experiment room one at a time. In the strangers condition, one participant is instructed to come 15 minutes before the other to prevent the participants meeting in the experiment room before the experiment. The same instructions introducing the experiment were read by the experimenter to each pair of subjects after they had both arrived(Appendix A).

For each of the four conditions the following protocol was followed

1. The condition was described using a common script.

2. Training (Visual and Haptic Interaction Models On)

    (a) The haptic interaction and the associated visual representation of the interaction was switched on and participants tried it out.

    (b) Participants were told the four emotions that they would be using the interaction model to convey and were instructed to try their ideas for communicating the four emotions.

(c) Participant One is given a list of five emotions

(d) Participant One conveys next emotion on list (for up to 16 sec.)

(e) Participant Two indicates which emotion they believe One is conveying (prompted after 16 sec.)

(f) Repeat (d-e) for each of the five emotions on the list.

(g) Repeat (c-f) but with Participant Two as the conveyer and Participant One as the receiver

3. Trials (Haptic Interaction Model On - no visual model)

    (a) Participant One given a list of 10 emotions

    (b) Participant One conveys next emotion on list (for up to 16 sec.)

    (c) Participant Two indicates which emotion they believe One is conveying (prompted after 16 sec.)

    (d) Repeat (b-c) for each of the 10 emotions on the list.

    (e) Repeat (a-d) but with Participant Two as the conveyer and Participant One as the decoder

4. Participants filled out a form indicating their strategies for conveying each of the four emotions(Appendix B).

At the end of the experiment, participants answered a questionnaire about their experience of the different conditions(Appendix C). On the questionnaire, we asked participants which interaction model they preferred, felt most connected to their partner through, felt most comfortable with, found the easiest to use to convey emotion and found the easiest to use to perceive emotion. We also asked them what they thought was good about each interaction model and what they would change about each interaction model.

4.4.4 Picking Emotions

The four emotion words used in this study were choosen to cover the emotion space and to be distinct from one another in this space. The emotions used were Angry, Delighted, Relaxed and Unhappy. These emotions were picked based on their placement in a two dimensional affect grid [34]. The affect grid is a tool developed for recording subjective emotion and is based on research showing that emotions can be represented in a two dimensional affect space. The grid is based on two orthogonal dimensions of valence (pleasure/displeasure) and arousal (sleepiness/arousal). Each quadrant of the grid is represented by an emotion word in our study.

Once the four emotion words were chosen, lists of these words were created for participants to convey. Lists of 20 emotion words (5 repetitions of each emotion) were created with the words in random order. The lists were divided in half. The first half was conveyed by one participant and the second half was conveyed by the other participant. If all instances of an emotion were in one half of the list, some adjustment was done so that each participant would convey each emotion at least once for each condition.

4.4.5 Recruiting Subjects

Subjects were recruited using the reservax hci@ubc web site and through posters posted on the University of British Columbia campus. For the pairs to be considered for the romantic pairs relationship, we asked that they be in a hetersexual, romantic relationship with each other for at least six months. For recruiting for the stranger pairs, we asked people not to intentionally sign up at the same time as someone they knew. When subjects arrived we made sure that they did not know the other.

4.5 Analysis

4.5.1 Emotions Conveyed Statistics

In order to test our hypotheses about performance, a repeated measures ANOVA was performed on number of trials in which emotion was successfully communicated for each condition using SPSS. The participants' responses to the subjective experience questions that asked them to pick an interaction model were analysed using χ^2 tests.

4.5.2 Exploration

Further exploration of the data provided interesting insight into how emotions were conveyed. One avenue of exploration was to look at which emotions were mistaken for one another. For example, it was possible that with this device conveying arousal would be easier than conveying valence. In this case, a table of sent versus perceived emotion would show that, in general, when Angry was conveyed either Angry or Delighted was preceived.

Another avenue of exploration was to look at the data, which we collected during the experiment, about participants' reported strategies for conveying emotion. We looked for common strategies for each emotion.

Chapter 5

Results

In this chapter, we discuss the study and the study results. The first section summarizes the demographic information about participants and statistics about the sessions. Next we talk about how we checked for an effect of ordering. The remaining sections present the quantitative results of the study. The first deals with how successfully participants could communicate emotion in the various experimental conditions. The second looks at the strategies participants reported using to communicate the four emotions in the study. In the third, we present some results related to participants' subjective reports of their interaction experience. The results reported in these three sections are all aggregated results. In the final section, we divide the results into groups to have a closer look.

5.1 Participants and Study Sessions

There were a total of 16 pairs (32 individuals) that participated in this study. Half (eight) of these pairs consisted of two individuals who did not know each other. We refer to these pairs as "strangers". The other half (eight) of these pairs consisted of individuals who had been in a romantic relationship together for at least six months. We refer to these pairs as "couples". "Partner" and "pair" are used to refer to any or all pairs regardless of relationship. "Individual" is used to refer to one person regardless of his/her relationship to his/her partner in this study. The participants were between 17 and 49 years old with a mean age of 24. Most were university students from various areas of study, one was a high school student and the rest were employed in different fields.

The study sessions typically lasted about two hours. The individuals in the stranger pairs were instructed to arrive 15 minutes apart and did not meet each other beforehand. However, in two cases the two individuals accidentally saw each other before the experiment. Couples arrived together. In both cases, pairs did not have an opportunity to discuss the interactions until the end of the study.

5.2 Ordering Effect

In the study, a Balanced Latin Squares design was used to mitigate any effect of condition order. There were four orderings of conditions each of which was used by four pairs (two stranger pairs and two couple pairs). Before doing our experimental analysis, we checked for an effect of order by adding order as a factor. We ran a repeated measures ANOVA on the data with order as a factor and found that there was not an order effect. Thus, for the rest of the analysis we did not consider order.

5.3 Ability to Communicate Emotions

In this experiment, we asked dyads to communicate emotion using a knob and a set of haptically rendered models. In this section, we look at how many emotions were successfully communicated under different conditions. Also, we examine the patterns in the communication and miscommunication of the four emotions: Angry, Delighted, Relaxed, Unhappy. Specifically, for each emotion we ask how often was it correctly perceived, and how often was it incorrectly perceived as one of the other three emotions. Further, we look at what patterns can be found in these miscommunications.

5.3.1 Overall Performance

Participants successfully communicated emotion in 54% of trials. If participants had selected from the four possible emotions at random then the expected mean success rate would be 25%. Thus while overall participants were not able to successfully communicate emotion with high accuracy they were able to successfully communicate some emotional information.

Looking at Table 5.1 or Figure 5.1, it is possible to see that each of the four emotions was perceived as the intended emotion more often than it was perceived as any other emotion. The results of the Pearson CHI-square test indicate that there is a statistically significant relationship ($p < 0.01$) between the sent and the received emotion.

	Sent Emotion			
Perceived Emotion	Angry	Delighted	Relaxed	Unhappy
Angry	62.2%	9.4%	2.5%	6.2%
Delighted	23.1%	49.2%	14.7%	15.3%
Relaxed	6.6%	24.8%	56.9%	30.8%
Unhappy	8.4%	16.3%	25.9%	47.6%

Table 5.1: Each column represents the emotion that the conveyer was trying to convey and each row is the emotion that the perceiver thought was being conveyed. The values are the percentage of trials (out of 320 for each column) that the row emotion was received when the column emotion was sent. The correct responses lie along the diagonal.

It is also possible to see that of the four emotions, Angry was most often identified correctly (62% of the time). Relaxed was next and was correctly identified 57% of the time. Unhappy and Delighted were correctly identified in slightly less than half the trials. These results correspond with participant comments at the end of the experiment. Several participants commented that Angry was

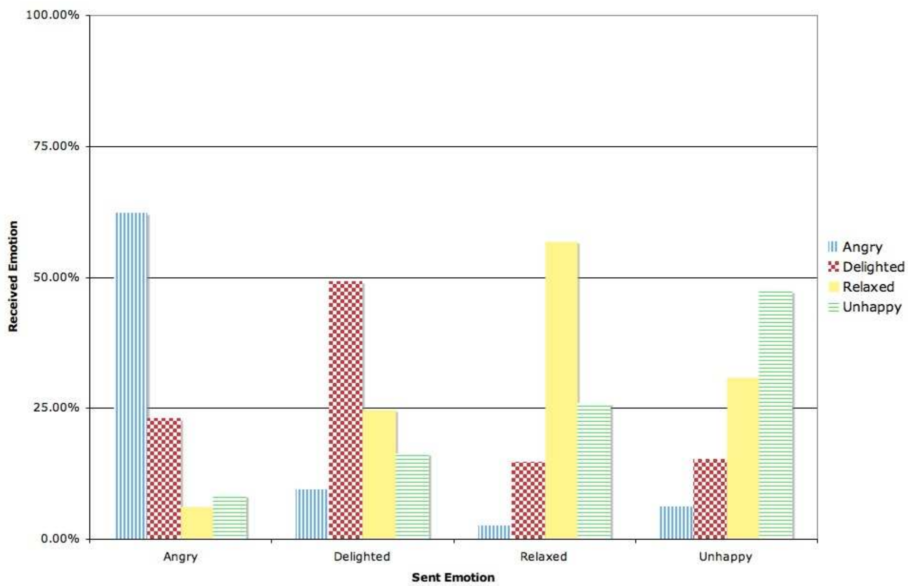

Figure 5.1: This graph shows how often each emotion the conveyers sent were perceived as the intended emotion and as each of the other emotions.

the easiest to convey and perceive and several indicated that Unhappy was the most difficult convey and perceive. During post-experiment discussion several pairs also discovered that they were using opposite strategies for Unhappy and Relaxed while others said Relaxed was easy.

When the an emotion was misidentified, it can been seen that for Angry, Unhappy and Relaxed the most common mislabel is the emotion with the same arousal level: Delighted, Relaxed and Unhappy respectively. For example, 61% of the time that Angry was perceived as something other than Angry it was identified as Delighted, which is the other high arousal emotion (33% would correspond to chance). It is interesting to note, however, that Delighted is very rarely misidentified as Angry. For each emotion the perceived emotion has either the same arousal and/or valence at a rate higher than chance (75%) as can be seen in Table 5.2.

Perceived Emotion	Angry	Delighted	Relaxed	Unhappy	Chance
same arousal	85.3%	58.6%	82.8%	78.4%	50%
same valence	68.9%	74%	71.6%	53.8%	50%
same arousal or valence	94%	83%	98%	85%	75%

Table 5.2: The percentage for each sent emotion where the received emotion had arousal/valence in the same direction as the target emotion, including when the target emotion was received.

5.3.2 Performance by Metaphor

There were two values of metaphor used in this experiment (Ping Pong, Hand Stroke).

We hypothesized that the metaphor used influences the ability of pairs to communicate emotion through a virtual haptic space. Specifically, participants will be able to successfully communicate emotion more frequently using the Hand Stroke metaphor than the Ping Pong metaphor.

Table 5.3 shows that a higher number/percentage of emotions were successfully communicated with the Hand Stroke metaphor than with the Ping Pong metaphor.

Metaphor	Mean # correct out of 40 trials ± S.E.	Mean Percent ± S.E.
Ping Pong	19.5 ± 1.4	$48.3\% \pm 3.5\%$
Hand Stroke	23.8 ± 2.1	$59.5\% \pm 5.3\%$

Table 5.3: Mean number and percent of trials during which emotions were successfully communicated. (Each cell represents an average of 16 pairs using the given metaphor, thus it is composed of $16 * 40 = 640$ observations)

On average participants successfully communicated emotion for four more trials (11% performance difference) using the Hand Stroke metaphor than with the Ping Pong metaphor; this difference is statistically significant at the $p < 0.05$ level ($p = 0.036$).

5.3.3 Performance by Space Indicator

In our experiment, half the trials utilized a haptic indicator of personal space and half did not. We hypothesized that the presence of a haptic indicator of personal space would affect the ability of pairs to communicate emotion; specifically, that pairs would have a higher success rate with a haptic indicator of personal space.

The data do not support this hypothesis for the indicator of personal space used in our study though other representations of space may generate different results. The means for the number of correctly identified emotions with the two space conditions are the same (54%). Overall, adding the indicator of space we developed to our interaction models did not affect the ability of participants to communicate emotion and we cannot reject the null hypothesis that an indicator of personal space does not affect ability to communicate emotion. However, an interaction effect between space and metaphor, which we discuss later in this chapter.

5.3.4 Performance by Relationship

Half the pairs in our study were strangers to each other and half were couples. We hypothesized that the type of relationship the pair shares would affect their ability to communicate emotion. Specifically, we hypothesized that couples would be more successful at communicating emotion than strangers.

Table 5.4 shows a trend for couples to be more successful at communicating emotion, with a performance difference of 11%. However, we are unable to reject the null hypothesis that relationship does not affect performance at the $p = 0.05$ level since $p = 0.124$.

Relationship	Mean # correct out of 80 trials	Mean Percent ± S.E.
Strangers	38.6 ± 2.4	$48.3\% \pm 3\%$
Couples	47.9 ± 5.0	$60.0\% \pm 6.5\%$

Table 5.4: Mean number and percent of trials during which emotion was successfully communicated. (Each cell represents an average of 8 pairs of the given relationship type. Thus it is composed of $8 * 80 = 640$ observations.

5.3.5 Interaction Between Experiment Factors

We also looked for any interaction effects among our main factors of metaphor, presence of a personal space indicator and relationship type.

Metaphor and Relationship We had hypothesized that there would be an interaction effect between relationship and metaphor. Specifically, we hypothesized that there would be a stronger effect of metaphor for romantic partners than for strangers.

The reason for this hypothesis was that we believed that couples would feel more comfortable with the more intimate Hand Stroke metaphor than strangers and thus would be better able to make use of it. The difference in the means between the metaphors for strangers is 4% and for couples it is 17%. However, there is not a statistically significant interaction($p = 0.182$).

Metaphor and Space An interaction effect was found between metaphor and space. Specifically, adding the indicator of personal space to the Ping Pong metaphor interaction improved performance (9% better with) but adding the indicator of personal space to the Hand Stroke metaphor interaction lowered performance (7.5% lower). This interaction effect is statistically significant at $p <= 0.05$ ($p = 0.006$).

Relationship	Metaphor	Mean # correct out of 40 trials ± S.E.	Mean Percent
Strangers	Ping Pong	18.5 ± 1.9	$46.3\% \pm 4.8\%$
Strangers	Hand Stroke	20.1 ± 1.0	$50.3\% \pm 2.5\%$
Couples	Ping Pong	20.5 ± 2.0	$51.3\% \pm 5.0\%$
Couples	Hand Stroke	27.4 ± 3.7	$68.5\% \pm 9.3\%$

Table 5.5: Mean number and percent of emotions that were successfully communicated as a function of relationship type and metaphor. Each cell represents an average of 8 pairs. Thus there were a total of $8 * 40 = 320$ trials for each combination of relationship type and metaphor

Metaphor	Personal Space	Mean # correct out of 20 trials ± S.E.	Mean Percent
Ping Pong	Indicator Off	8.9 ± 0.8	$44\% \pm 4\%$
Ping Pong	Indicator On	10.6 ± 0.8	$53\% \pm 4\%$
Hand Stroke	Indicator Off	12.6 ± 1.1	$62\% \pm 5.5\%$
Hand Stroke	Indicator On	11.1 ± 1.1	$55.5\% \pm 5.5\%$

Table 5.6: Mean number and percent of trials in which emotions were successfully communicated. Each cell represents an average of 16 pairs, thus it is composed of $16 * 20 = 320$ observations

5.4 Strategies for Communicating Emotion

In this section, we present participants' reported strategies of conveying and perceiving emotion.

5.4.1 Strategies for Conveying Emotion

After each condition, participants were asked to fill in a form (Appendix B) indicating which actions they used to communicate each emotion. The form contained eight actions (listed below) and room for participants to add in up to three additional actions.

- hold still
- move slowly
- move quickly
- hit gently
- hit hard
- move close
- move far away
- repeat an action

We are interested in using the participants' reported actions to see if there are any commonalities in strategies, where a "strategy" is defined as the subset of actions that participants reported using for conveying the four emotions in the various experimental conditions. Overall metaphor, space and relationship type did not have a significant impact on the number of participants who reported using each action for a particular emotion. We also looked at aggregated results and present those here.We combine the strategies for each of the 32 participants where each participant reported four strategies for each emotion (one for each combination of metaphor and presence or absence of personal space indicator) for a total of 128 reported strategies for each emotion.

Figures 5.2 and 5.3 show two views of the participants aggregated reported strategies for conveying each emotion. Figure 5.2 shows an action profile for each emotion; where as, Figure 5.3 gives an emotion profile for each action. For each metaphor and space condition, for each action participants either reported using the action or not using it for each emotion. Thus both these figures show sums of the number of times an action was reported as being used for an emotion.

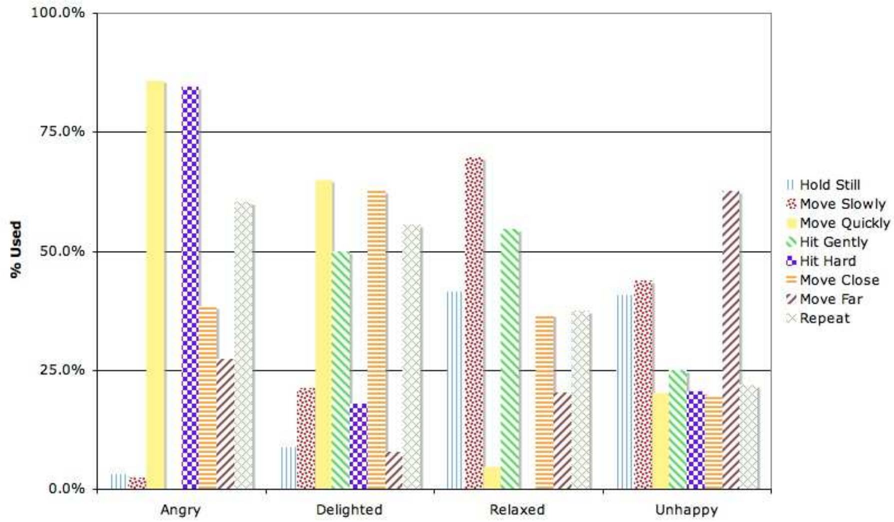

Figure 5.2: The percentage of times the actions were reported as being used organized by emotion, aggregated across all subjects and for all combinations of metaphor and personal space indicator.

For each emotion there is at least one action that is frequently (> 50%) used to convey it and not often used to convey any other emotion. Table 5.7 lists the frequently used / potentially distinguishing actions for each emotion.

Move Quickly is almost always used for Angry and frequently used for Delighted but rarely used for Relaxed or Unhappy and thus differentiates Angry and Delighted from Relaxed and Unhappy. *Hit Hard* is almost always used for Angry and rarely used for Delighted, thus differentiating Angry from Delighted. The most frequently reported action for Relaxed is *Move Slowly*. This action is rarely (< 25%) used for Angry and Delighted but is sometimes (about 44%) used for Unhappy. However, *Move Far* away is frequently used for Unhappy (about 62%) and rarely used for Relaxed (< 21%).

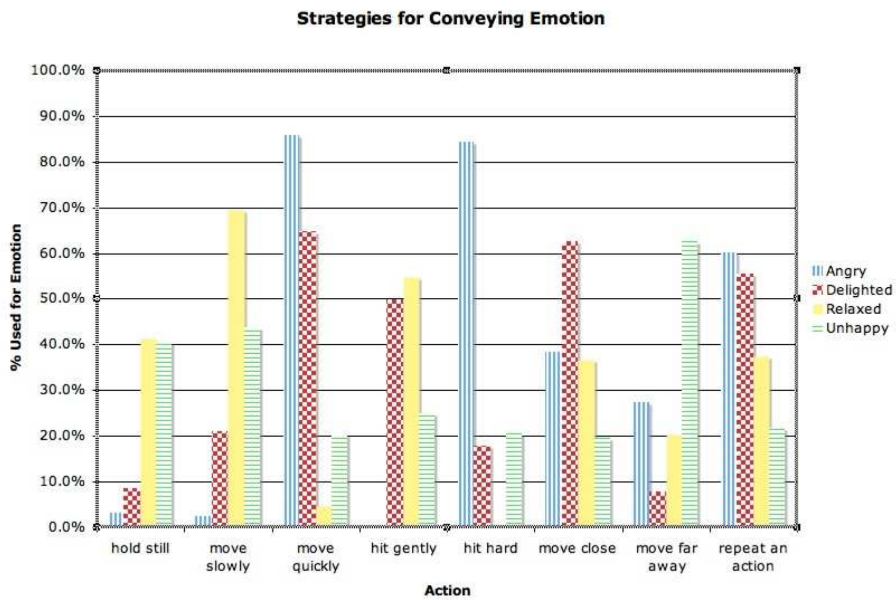

Figure 5.3: The percentage of times an actions was reported as being used for each emotion organized by action, aggregated across all subjects and for all combinations of metaphor and personal space indicator.

5.4.2 Strategies for Perceiving Emotion

In the questionnaire at the end of the study, participants were asked about their strategy for perceiving emotion. The haptic model is dynamic and the force feedback depends on both participants, thus when perceiving a participant could choose to stay still and feel what the other was doing or could actively engage in the interaction to determine the emotion. In the final questionnaire, participants were asked if they moved or remained still in order to feel the emotion being conveyed. The majority of participants (26/32 or 80%) indicated that they remained still. 19% of these participants also indicated that it depended on the interaction or the emotion they thought they were receiving. The 6 participants that did not report staying still indicated that it depended on the interaction

Emotion	Action	% used for this emotion
Angry	Move Quickly	86%
	Hit Hard	84%
Delighted	Move Quickly	65%
	Move Close	63%
	Hit Gently	50%
Relaxed	Move Slowly	70%
	Hit Gently	55%
Unhappy	Move Far Away	63%

Table 5.7: The actions reported as being used in > 50% of the strategy reports (all participants and conditions, 32 X 4) for each emotion.

and/or the emotion they thought they were receiving. The relationship of the participant to his/her partner did not significantly affect the response to this question.

5.4.3 Strategies for Interacting

In the final questionnaire, participants were also asked about how their partner's actions influenced their actions. When asked if as the perceiver they found that they would express a perceived emotion back to the conveyer, 63% (20/32) of the participants indicated that they would mirror the emotion that they thought was being conveyed. When participants were asked if they changed their strategy to be closer to the strategy they perceived their partner to be using, 72% (23/32) said yes. Again these responses did not depend significantly on relationship.

5.5 Subjective aspects of Interaction Experience

Communicating emotion is a very social task and as such we are interested not only in participants' performance and communication strategies but also in their experience of the interaction. In the final questionnaire, we asked participants to choose which interaction they preferred, felt most connected to their partner through, felt most comfortable with, found the easiest to use to convey emotion and found the easiest to use to perceive emotion. We hypothesized that for each of these questions the couples would select the more intimate metaphor interaction (Hand Stroke) and the strangers would select the more game like interaction metaphor (Ping Pong). We also hypothesized that participants would choose interactions with an indicator of space regardless of relationship type.

5.5.1 Preference

As hypothesized, strangers tend to prefer the Ping Pong interaction whereas couples prefer the Hand Stroke interaction Table 5.8. The association between relationship and metaphor is statistically significant ($\chi^2 = 6.35$, $p < 0.012$). The strength of this association is weakly positive($phi = 0.445$, $p < 0.012$).

Preference for presence of a personal space indictor did not depend on relationship or preferred metaphor and 81% (26/32) participants preferred an indicator of personal space ($\chi^2 = 34$, $p < 0.001$). This χ value is obtained when the expected frequencies for preference for space on, off or same (no space preference) are the same. It should be noted that this preference for a personal space indicator may only apply to the preferred metaphor.

Relationship	Space Indicator	Ping Pong	Hand Stroke
Strangers	Off	2	2
	On	8	4
	Total	10	6
Couples	Off	0	1
	On	3	11
	Either	0	1
	Total	3	13
Total		13	19

Table 5.8: The number of participants that preferred each interaction according to metaphor and presence of a indicator of personal space. (out of a total of 32 participants) (one participant indicated that the presence or absence of a personal space indictor did not make a difference - i.e. *Either* on or off was equally preferred by this users)

5.5.2 Connection

The feeling of connection was not associated with the type of relationship(Table 5.9). Most participants (84%) choose the Hand Stroke metaphor as the one with which they felt most connected and most participants (81%) choose presence of an indicator of personal space as the space condition by which they felt most connected. These connection results are statistically significant with $\chi^2 = 15$, $p < 0.001$ for metaphor and $\chi^2 = 34$, $p < 0.001$ for space.

5.5.3 Comfort

As hypothesized, strangers tended to feel more comfortable using the Ping Pong interaction whereas couples tended to feel more comfortable with the Hand Stroke interaction (see Table 5.10). This interaction is statistically

Relationship	Space Indicator	Ping Pong	Hand Stroke
Strangers	Off	1	2
	On	3	10
	Total	4	12
Couples	Off	0	2
	On	1	12
	Either	0	1
	Total	1	15
Total		5	27

Table 5.9: The number of participants that felt the most connected using each interaction according to metaphor and presence of a indicator of personal space. (out of a total of 32 participants)

significant($\chi^2 = 8.5$, $p < 0.003$) and the association between relationship and chosen most comfortable metaphor is a weak positive association($phi = 0.516$, $p < 0.003$).

Regardless of relationship and chosen most comfortable metaphor, people generally felt more comfortable with an indicator of personal space present (78%, $\chi^2 = 30$, $p < 0.001$).

5.5.4 Perceived Ability to Convey

As hypothesized, couples indicated that it was easiest to convey emotion with the Hand Stroke metaphor with an haptic indicator of personal space present (see Table 5.11). However, strangers were more evenly divided on this question with just less than half saying it was easiest to convey emotion with the Ping Pong metaphor and just over half saying that it was easiest to convey emotion with the Hand Stroke metaphor. However, like couples most strangers indicated that they found it easiest to convey emotion when there was a haptic indicator

Relationship	Space Indicator	Ping Pong	Hand Stroke
Strangers	Off	2	2
	On	8	4
	Total	10	6
Couples	Off	0	2
	On	2	11
	Either	0	1
	Total	2	14
Total		12	20

Table 5.10: The number of participants that felt the most comfortable using each interaction according to metaphor and presence of a indicator of personal space. (out of a total of 32 participants)

of space with their chosen metaphor.

Thus we find support for our hypothesis that couples will find it easiest to convey emotion with the Hand Stroke metaphor but not for our hypothesis that stranger will find it easiest to convey emotion with the Ping Pong metaphor.

Overall the Hand Stroke is more frequently perceived as being easier to convey emotion with and this is statistically significant ($\chi^2 = 15$, $p < 0.001$). Both groups indicated that they found it easiest to convey emotion using their chosen metaphor with a haptic indicator of personal space(81%, $\chi^2 = 33$, $p < 0.001$).

5.5.5 Perceived Ability to Perceive

Overall, participants found it easier to perceive emotion using the hand stroke metaphor with an indicator of personal space. These results are statistically significant with $\chi^2 = 8$, $p < 0.005$ for metaphor and $\chi^2 = 30$, $p < 0.001$ for space.

Relationship	Space Indicator	Ping Pong	Hand Stroke
Strangers	Off	0	3
	On	6	6
	Same	1	0
	Total	7	9
Couples	Off	0	1
	On	1	13
	Either	0	1
	Total	1	15
Total		8	24

Table 5.11: The number of participants that felt the best able to convey emotion using each interaction according to metaphor and presence of a indicator of personal space. (out of a total of 32 participants)

5.6 Performance and Strategies for Conveying

In this section, we examine the relationship between strategy for and success at conveying emotion. We divide the data for each pair according to direction, which partner was the conveyer. We then group the conveyers, into three groups, based on how many emotions were successfully communicated when they were conveying. Finally we look at the communication patterns within these three groups.

5.6.1 Success by Conveyer

Based on the natural distributions of success rate by conveyer(Figure 5.4) we divided the conveyer data into three groups. Two groups contain the majority of conveyers. The first, which corresponds to the region around the first mode in the Figure 5.4, contains conveyers who successfully conveyed emotion in $11-$

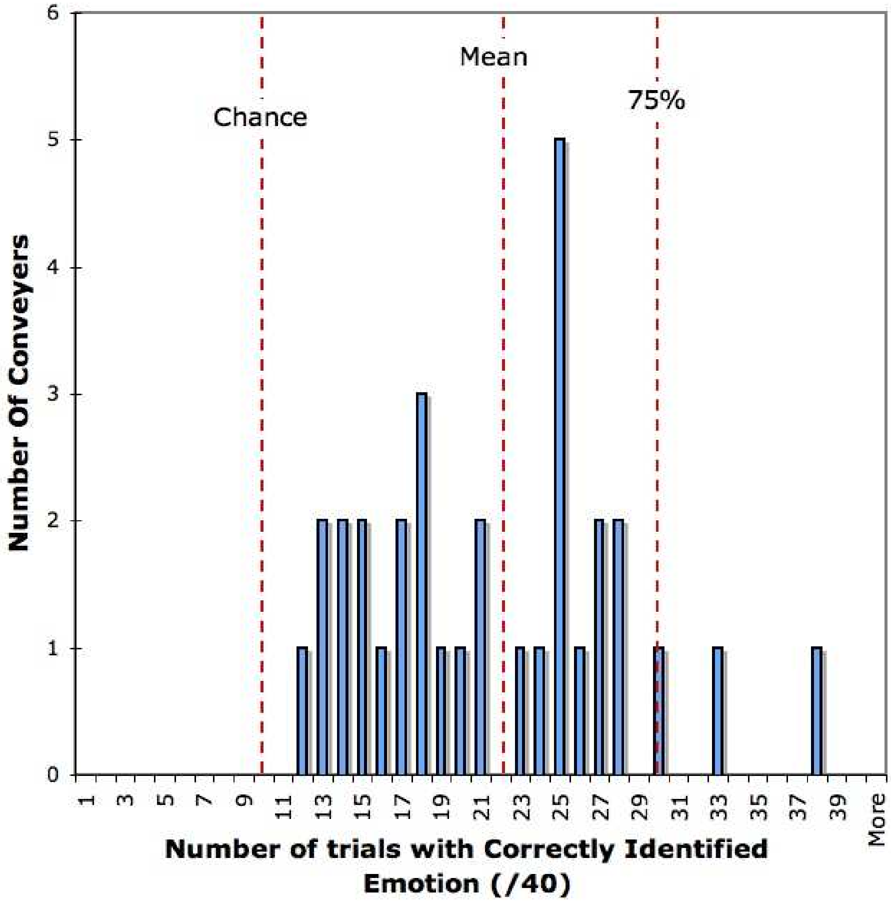

Figure 5.4: This histogram shows how many conveyers were able to successfully convey a particular number of emotions out of 40 trials.

Relationship	Space Indicator	Ping Pong	Hand Stroke
Strangers	Off	1	4
	On	5	6
	Total	6	10
Couples	Off	0	1
	On	2	12
	Either	0	1
	Total	2	14
Total		8	24

Table 5.12: The number of participants that felt the best able to perceive emotion using each interaction according to metaphor and presence of a indicator of personal space. (out of a total of 32 participants)

21 trials. This is the group that successfully conveyed emotion in a greater number of trials than chance but less than the overall average. The second group, which corresponds to the second mode in the graph, contains conveyers who successfully conveyed emotion in $22 - 29$ trials. This group was successful conveying in a greater than average number of trials but in less than 75% of the trials. The remaining group contains the three conveyers that do not fit in either of these groups. These three conveyers successfully conveyed emotion in at least 75% of the trials. It should be noted that while we divide by conveyer, success at communicating the emotions also depends on the ability of the perceiver, which remains a constant for each conveyer in this study.

5.6.2 Below Average

We combine the strategies of all the conveyers in the below average group (17 participants) for conveying emotions(Figure 5.5). Comparing the strategies of this group with the strategies of all the conveyers(Figure 5.2) we see that the action use profiles look similar with only a few differences. The biggest difference is that this group uses *move far away* less often for Unhappy. We also see that *move close* is less frequently used for Delighted and Relaxed.

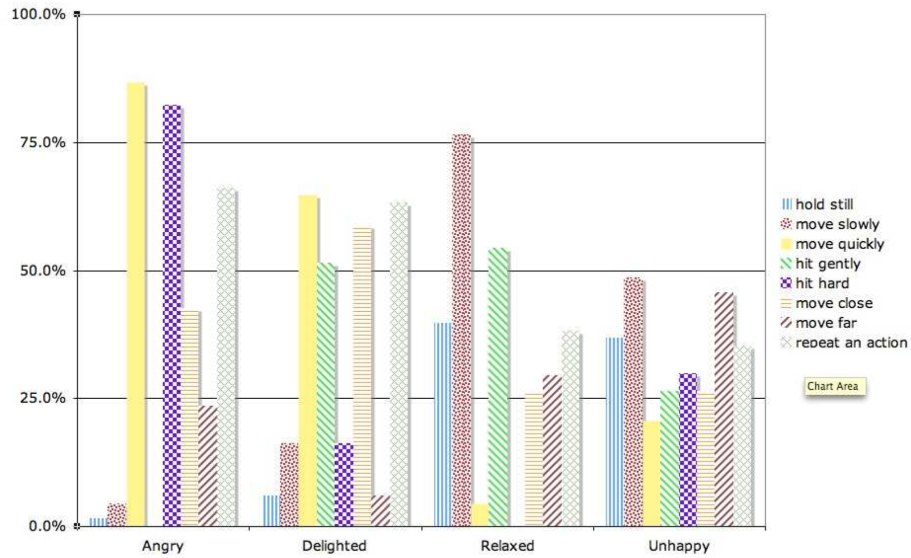

Figure 5.5: This graph shows the strategies that below average conveyers reported using for each emotion.

Looking at the sent v.s. the received emotions for the below average conveyers (see figure 5.8) we see that there is more confusion overall. Anger is misidentified 7% more often and 6% is from it being mistaken as Delighted. The other emotions are all misidentified more than 10% more frequently. Both Delighted and Relaxed are much more frequently misidentified as Unhappy and Unhappy is identified as Relaxed more often than as Unhappy.

5.6.3 Above Average

We combine the strategies of all the conveyers in the above average group for conveying emotions(Figure 5.7). Comparing the strategies of this group with

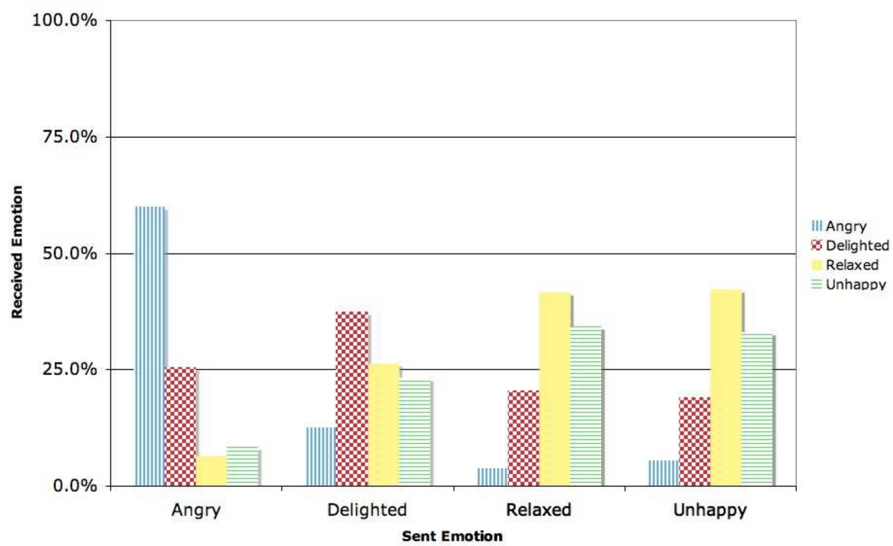

Figure 5.6: This graph shows how often each emotion the below average conveyers sent were perceived as the intended emotion and as each of the other emotions.

the strategies of all the conveyers(Figure 5.3) we see that generally the actions are used in the same ways. The one obvious difference; however, is that *move far away*, which is the differentiating action for Unhappy we identified earlier, is used considerably more often by the above average group.

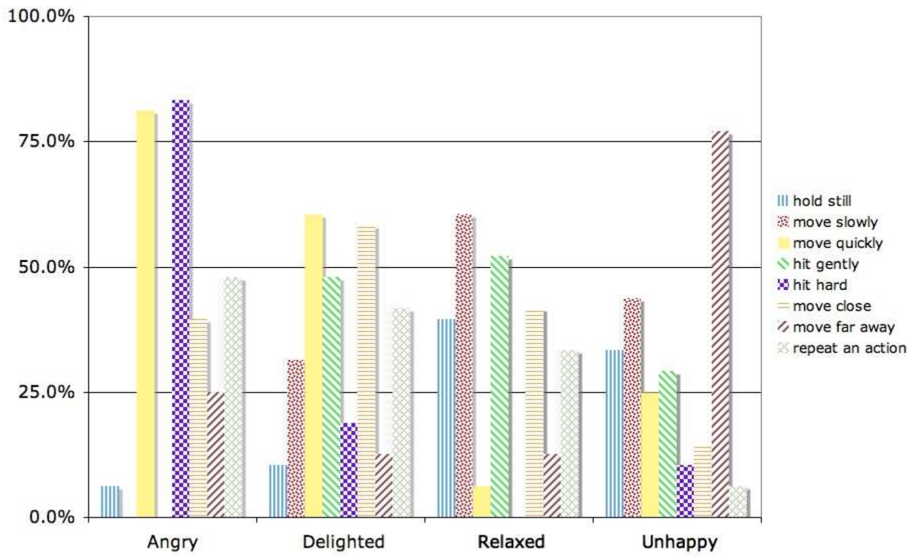

Figure 5.7: This graph shows the strategies that above average conveyers reported using.

Looking at the sent v.s. the received emotions for this group(Figure 5.8) we see that Angry and Relaxed were both correctly identified 70% of the time. This is an increase over the overall average of 9% and 14% respectively. Unhappy was also correctly identified at a rate about 9% higher than the overall average. There was only a 2% increase in the number of times that Delighted was correctly identified. A large portion of the difference between the overall success and the success of this group comes from Unhappy and Relaxed being less frequently confused.

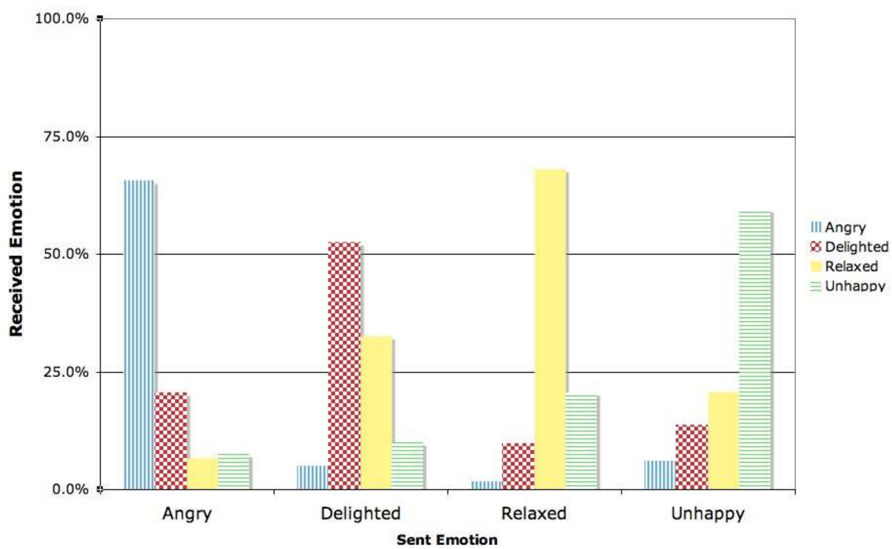

Figure 5.8: This graph shows how often each emotion the above average conveyers sent were perceived as the intended emotion and as each of the other emotions.

5.6.4 Most Successful

There were three conveyers who were able to successfully convey emotion in more than 75% of trials. Two of these individuals were in the same pair, and overall this pair was able to successfully communicate the emotions in 89% of trials. Instead of looking at the three conveyers in this group, here we take a closer look at the performance and reported strategies and experience of this high performance pair.

This pair was a couple. Looking at how they did across conditions Table 5.13 we can see that this couple was always able to successfully communicate in the Hand Stroke metaphor trials. Looking specifically at the miscommunications with the Ping Pong metaphor (results not shown) it is possible to see that without an indicator of space the miscommunications are all confusions between the two high arousal emotions: Angry and Delighted. Furthermore, in one direction these emotions were consistently switched, which suggests the two individuals in this pair could differentiate the signals they were using but that one partner mapped the other's Angry to Delighted and Delighted to Angry. With space, the mistakes are a bit more spread out though again they are again mostly in one direction.

Metaphor	Space Indicator	Success Rate
Ping Pong	Off	80%
Ping Pong	On	75%
Hand Stroke	Off	100%
Hand Stroke	On	100%

Table 5.13: The "most successful" couple was able to successfully communicate the four emotions every time with the Hand Stroke metaphor.

In general, this couple had a strategy for each emotion that was different from every other emotion. The strategy profile were similar though not always the same and were relatively consistent across conditions; although Relaxed and Delighted were sometimes different. During the interview after the study this pair described their strategies as being the same across conditions for each emotion except for Delighted, which varied depending on the interaction. For all of the interaction experience questions on the final questionnaire (preference, connection, comfort, ability to convey, ability to perceive) both the participants of this pair selected the Hand Stroke metaphor with space.

Chapter 6

Discussion

The purpose of this thesis is to explore how the design of a haptic interaction for dyads and dyads' relationship affects performance in a communicating emotions task, as well as individual's subjective experience. In our work, we decided to focus on (a) the metaphor used to develop and explain the virtual space of the interaction; (b) presence or absence of a haptic indicator of distance from the other in the virtual space; and (c) the intimacy of the relationship. In the previous chapter, we presented the results from our experiment. In this chapter, we discuss the possible meanings and implications of these results.

We first look in Section 6.1 at each of the control variables: metaphor, space and relationship, and their impact on the assigned task of communicating emotions. The remaining sections explore implications that come out of looking at various results across conditions and/or relating to the strategies used to communicate emotion. In Section 6.2, we explore the relationship between emotion, communication strategy and task performance. In Section 6.3, we discuss the notion of a haptic interaction model having a expressive capacity as one of its defining characteristics. Next we discuss how participants used real world knowledge in the virtual space(Section 6.4). Our experimental explorations were driven by the hypothesis that a haptic interaction model could provide a useful emotional communication channel for distributed dyads. In Section 6.5, we evaluate the validity of this assumption based on the results of our experiment. Finally, in Section 6.6, we discuss some considerations that should be taken into account when interpreting the results of our experiment or designing similar experiments in the future.

6.1 How Design of an Interaction Model and Relationship Influence Interaction

In this section, we discuss the implications of results (performance and subjective responses) due to the three variables of metaphor, personal space indictor and relationship.

6.1.1 Metaphor

Based on our experiment results, metaphor is a significant factor in both performance and subjective experience. We chose the two metaphors for our experiment based on their relative distance from each other in terms of intimacy of haptic interaction. Ping Pong is a low intimacy interaction and Hand Stroke is a high intimacy interaction. One other related difference between these two interaction metaphors is the level of indirection: the actions of one's partner can be felt indirectly in the Ping Pong interaction and directly in the Hand Stroke interaction. For some of the differences found between these two metaphors it is not possible to say if it is the intimacy, the indirection or another factor that is the key factor, but results suggest that it may be a combination of intimacy and indirection, as will be discussed below.

The Hand Stroke metaphor appears to better facilitate both actual and perceived task performance. The results suggest that this may be due both to the directness and to the intimate nature of this metaphor. If it was only the intimacy of the interaction affecting the performance, then we would expect strangers' actual and perceived performance to be better with the less intimate Ping Pong metaphor; however, their actual and perceived performance is better with the Hand Stroke metaphor. If it was only the direct interaction style of the metaphor that lead to this higher performance, we would expect the performance difference between the metaphors to be the same regardless of the relationship of the dyad. However, this is not the case as the performance increase for the Hand Stroke metaphor is larger for couples than for strangers (though this result is not statistically significant). As well, the Hand Stroke metaphor is perceived overall as being easier to convey and perceive emotion with, but this perception is less common among strangers than couples (though this result is also not statistically significant).

The metaphor also affects other subjective aspects of the interaction, such as preference, feeling of connection and comfort. Overall the Hand Stroke metaphor is preferred and creates a greater sense of connection. This metaphor is also found to be more comfortable for couples. These findings are likely a result of the increased intimacy of the interaction and a greater perception of success using this interaction. The greater sense of connection is found in both strangers and couples. When split by relationship, couples prefer and are more comfortable with this metaphor but strangers prefer and are more comfortable with the Ping Pong metaphor. This difference depending on relationship suggests that it is the intimacy of the metaphor influencing this aspect of the user experience.

6.1.2 Space

During the experiments two variants of each metaphor were used: one with an additional haptic vibration to indicate personal space and one without such a vibration. Looking at the overall performance results, this additional vibration did not make a difference in performance; however, looking more closely we see that the story is more complex. Specifically, there is an interaction effect between metaphor and space. When used in combination with the Ping Pong metaphor, the additional space vibration increase performance but it decreases performance when added to the Hand Stroke metaphor. We examine this further in Section 6.3.

Despite lack of improvement in overall performance results there is a strong argument for including such a space indicator based on the reported subjective experience. Specifically, a large and statistically significant majority of participants preferred, felt more connected, and felt more comfortable with a spatial indicator added to the metaphor that they most preferred, felt most connected with and felt most comfortable with respectively. Participants also indicated that it was easier to convey and perceive emotion with a spatial indicator but this could be positive or negative depending on the relative importance of perceived versus actual performance. Specifically, a higher perceived performance than actual performance is likely at first to encourage continued use of the interaction and potentially leading to increased performance. However, it may also lead to problematic miscommunications that result in the interaction being abandoned entirely.

Thus overall subjective results suggest that an additional haptic indicator of person space is desirable; however, performance results suggest that the spatial vibration used in this study was not successful at increasing performance. It is possible that a different spatial signal would result in better performance results. Another possibility is that dyads could make effective use of such an indicator only in situations that provide context or other feedback cues.

6.1.3 Relationship

The relationship shared by dyads interacting through a haptic device affects the interaction. In terms of performance, there were no statistically significant performance differences, but couples did better than strangers overall. In terms of subjective experience, however, differences are significant: strangers prefer and are more comfortable with the Ping Pong metaphor, whereas, couples prefer and are more comfortable with the Hand Stroke metaphor.

Observations during the experiment and participants' written comments suggest that intimate metaphors such as the Hand Stroke metaphor may cause discomfort if used by people who are not in an intimate relationship. Several participants in stranger pairs indicated on their final questionnaires that the Hand Stroke made them uncomfortable. Furthermore, after the experiment in at least half of the stranger pairs, one or more of the participants did not want to meet the person they had been interacting with, though this may also be a result of other aspects of the study. In one case where participants were happy to meet, they joked about the sensation of the Hand Stroke metaphor before moving on to discussing the interaction. Similarly, some couples commented that they felt like they were touching when using the Hand Stroke metaphor.

Couples have an apparent advantage over strangers when developing their strategy for communicating in that they know their partner's real world communication strategies. However, for at least one couple this actually became a hindrance. During the discussion at the end of their session they discovered that they had been using different strategies. Specifically, he had used what he thought were the most obvious mappings based on common means of expressing emotion and she had tried to use knowledge of how he would act in face-to-face situations, which was in some cases different from the common means. Thus, to successfully communicate in this experiment, which intentionally did not permit collaboration in preparation of a shared strategy, both partners of a couples independently had to decide how much of their knowledge of each other's face-to-face interaction styles they should port to the haptic interaction.

6.2 Communicating Emotion: Action Strategies

Here, we discuss the interactions between strategy and success at conveying emotion. Recall that in Section 5.4.1, we identified unique actions that were commonly used for each emotion. The existence of common interaction strategies, even in absence of collaborative strategy planning, suggests that there may be a natural action-to-emotion mapping that a majority of participants were using. We hereafter term the set of the actions commonly used to express an emotion as its action fingerprint. Each emotion's action fingerprint contains either a unique action or set of actions that are not commonly used to convey the other emotions. Thus the aggregated strategies for each emotion suggest that if these unique finger print actions are distinguishable in the interaction, then using the finger print actions for each emotion would make it possible for the four emotions to be successfully communicated.

Looking at the use of an emotion's finger print actions and the success rate at identifying that emotion we can see a correspondence(Table 6.1). Specifically, the more consistently an emotions action fingerprint strategy was used the more frequently this emotion was successfully communicated.

In Section 5.6.1, we divided the data by conveyer according to success rate of communication. In the "below average" group, Angry is misidentified as Delighted more often than the overall average. This is probably because *move close*, which is the main difference between the Angry and Delighted action finger prints, is less frequently used for Delighted by this group. This group used *move far away* less frequently to express Unhappy and both Delighted and Relaxed are more frequently misidentified as Unhappy by this group. Furthermore, Unhappy is identified as Relaxed more frequently than it is correctly identified. This reflects the observation that there is no common identifying characteristic action used for Unhappy by this group. In the above average group, the oppo-

Emotion	Action Fingerprint	% Conditions People Reported Using this Action for this Emotion	% of Trials This Emotion Successfully Communicated
Angry	Move Quickly	86%	62%
	Hit Hard	84%	
Delighted	Move Quickly	65%	49%
	Move Close	63%	
	Hit Gently	50%	
Relaxed	Move Slowly	70%	57%
	Hit Gently	55%	
Unhappy	Move Far Away	63%	48%

Table 6.1: Use of finger print strategies for each emotion and rate at which each emotion was successfully communicated.

site trends can be seen. Most obvious is the increase in the use of *move far away* for Unhappy and the decrease in the confusion between Relaxed and Unhappy.

Thus default strategies emerged for each emotion; and using these unique and distinctive strategies improved performance. In other words, using common strategies in this new interaction medium, as using common strategies with new acquaintances in face-to-face interaction, means you are more likely to be understood. Were people to use this interaction medium extensively, we might expect people and pairs to develop their own unique strategies. This is similar to the observation that in face-to-face interaction people develop unique nonverbal interaction patterns, which replace conventional strategies as the relationship between them develops [21].

6.3 Expressive Capacity of Interaction Models

It is possible to think of a haptic interaction model as having a certain level of expressive capacity. The expressive capacity of an interaction relates to how much information it is possible to uniquely convey and differentiate with that interaction. Our results suggest that having an expressive capacity that matches the task leads to better performance.

6.3.1 Metaphor and Space - Experimental Interaction Effect

Adding a haptic indicator of personal space to the Ping Pong interaction increased the average number of emotions successfully communicated; however, adding a haptic indicator of personal space to the Hand Stroke interaction decreased the average number of emotions successfully communicated. Adding space to Ping Pong supplies information that is missing without a space indicator. Specifically, without the space indicator it is not possible to determine if the other is close or far in the virtual space. On the other hand, adding an indicator of space to hand stroke adds some additional information about the haptic context but if hands stay touching then the space indicator is not providing anything new. Without the space indicator in hand stroke it is still possible to indicate close and far by touching / not touching so adding space adds granularity and redundancy in distance information rather than providing something entirely new.

The results and participants' comments suggest that without a spatial indicator it is difficult to find means to differentiate the four emotions with the Ping Pong metaphor; whereas, for the Hand Stroke metaphor, adding a spatial indicator increases the expressiveness of the interaction beyond what is required of the task. People who could communicate well with Hand Stroke without space did not always know how to use additional information and one participant commented she needed to think with space as opposed to just feeling, without it.

This suggests that performance was best when the expressive capacity of the interaction was such that it was just enough for the task. Extra expressive capacity introduced added confusion.

6.3.2 Desired Expressiveness

Even though the performance is highest in the Hand Stroke without the space indicator condition, the perceived performance was higher with a spatial indicator regardless of which metaphor was chosen. As well, most of the participants who prefer the Hand Stroke metaphor prefer it with space. It is possible that people prefer greater expressive power even when they are unable to use it. Perhaps over time they would find ways to harness it and be able to communicate a wider range of emotional states. This is quite speculative based only on our limited results. Waisvisz suggests that musical expressiveness is related to the effort required to create the music [28]. Thus it may be desirable for longer term use to have a haptic interaction whose expressiveness is beyond what can be learned and utilized in a two hour experiment.

6.4 Real World Influences Virtual Interaction

There are several ways in which we observe the participants using the interaction metaphor to translate real-world, face-to-face practices into this virtual haptic interaction. This is seen both in (a) the strategies people use to convey the four emotions, and (b) the differences between strangers and couples in reported subjective experience.

6.4.1 Strategies

Distance Indicator and Valence Those who study face-to-face interaction have found the people tend to interact at physically closer distances in pleasant situations, and farther apart in unpleasant situations [10]. Thus in face-to-face interaction, distance is correlated with valence. The reported strategies of the participants suggest that they brought a similar interaction pattern into the virtual space. Specifically, *move close* is one of the finger print actions for the positive valence emotion Delighted, and *move far away* is the finger print action for the negative valence emotion Unhappy.

Speed Indicates Arousal Participants in our study used speed of motion to indicate the arousal level of the emotion. For Angry and Delighted, *move quickly* is one of the fingerprint actions. For Relaxed, *move slowly* is the most frequently reported action. For Unhappy, neither *move quickly* or *move slowly* are frequently used, but this is likely because participants used *moving far away* for Unhappy, thus avoiding interaction at any speed. Thus participants conveyed arousal level in the virtual interaction by using higher speeds (higher energy) for high arousal emotions and lower speeds (lower energy) to convey low arousal emotions.

Couple Strategies Another place where there is evidence that people use strategies from face-to-face interaction in the virtual haptic interaction comes from couples. For at least three of the couples in our study, knowledge about their partner's real world communication strategies affected the virtual interaction. In one couple, one partner decided to use this knowledge and the other decided to use what he thought of as the "default" actions, resulting in miscommunication. When asked if they thought knowing each other helped them to do the task, one person indicated that it might be easier without knowing each other since they could then use 'defaults' instead of tailoring the interaction to their partners communication style. Another person indicated to the experimenter that for part of the experiment she had being interpreting her partner's signals the way that she would convey the emotions but eventually realized that he would do it differently.

6.4.2 Relationship and Metaphor

The final indication that people bring real world experience into the virtual haptic interaction via the metaphor of interaction is the difference in metaphor preference and comfort between strangers and couples. The discomfort that some strangers felt was such that they did not want to meet their partner and/or commented on it in the final questionnaire. Furthermore, two of the strangers reported finding the hand stroke interaction sexual. Couples, on the other hand, generally preferred and felt more comfortable with the hand stroke metaphor. Some even commenting that it felt as if they were touching. As in real world interactions, comfort is greater when the intimacy of the interaction is appropriate for the relationship [18].

6.5 Success as an Emotional Communication Device

We designed our experiment to examine the effect of several different haptic interaction model designs on performance and interaction experience during an emotional communication task. Underlying our design is the assumption that a computer mediated haptic communication setup, such as the one used in our experiment, could be useful for dyad emotional communication. Our experiment was not designed to test this assumption; however, it is important to examine it, and in this section, we evaluate this assumption based on our experimental results and observation.

Experimental Considerations Since our experiment is not designed to test this assumption, it is important to consider the aspects of our design that prevent us from making a definitive claim about the validity of this assumption. Firstly, participants in our experiment were asked to convey various emotions on a list, and thus they were intentionally conveying cognitive emotion and not felt emotion. It is not obvious that felt emotion would lead to the same behaviour as cognitive emotion, but as is noted by Collier [10] cognitive emotion is a good first approximation of felt emotion. Secondly, the task we asked participants to perform is more difficult than using such a device in real world interaction since there was no context within which the haptics signals could be understood. Also participants did not have any external feedback or other communication channel available by which to co-ordinate their use of the interaction models. Finally, the task we asked participants to perform was easier than using such a device in the real world since it was limited to four fairly distinct emotion rather than the full spectrum of human emotional experience. Overall, we would expect that ability to use context to learn their partner's strategies and modify their own use of the interaction would lead to better performance in real-world interactions.

Performance The performance of participants suggests that considerable emotional information is communicated. The overall average is slightly more than twice what would be expected by chance, and almost all of the trials the arousal or valence of the emotion is successfully communicated. Furthermore, each emotion is correctly identified more often than it is identified as one of the other emotions.

The high success rates of some pairs at communicating emotion suggests that it is possible for some people to develop and use a language for communicating cognitive emotion with our interaction models even without external feedback or context. The successfully communication of emotions in at least 90% of trials in at least one of the Hand Stroke metaphor conditions by five couples (out of eight) suggests that given the right interaction and sufficient knowledge of the other it is possible to communicate emotional information through such a device.

Connection A number of couples commented that they enjoyed the feeling of connection they felt with each other while using the interactions. Perhaps more compelling is the fact that individuals involved in strangers pairs indicated discomfort with the interaction, particularly with the Hand Stroke metaphor. This is the strongest indication that some form of true connect can be achieved with this type of interaction. Given that this type of connection can be achieved, creating a successful computer mediated haptic interaction is a matter of working out the details of such an interaction.

Reported Behaviour and Comments A majority of participants reported adapting their strategy to reflect the one they felt their partner was using. The performance results suggest that this adaptation was not necessarily successful; however, given more context or co-ordination it is likely that this tendency to adapt communication styles would lead to greater communication success and interest. Several participants also indicated at the end of the experiment that they felt they would have been able to do well or at least better if they had been able to come up with a communication strategy together.

Some participants offered comments about whether this kind of mediated touch interaction would be appropriate for communicating emotion. Specifically, one participant did not think that this type of interaction would be a very easy way to communicate emotion since "touch isn't something you do that often." When asked if the task was difficult, another participant indicated that he did not find it difficult but that it was not interesting to him. On the other hand, another participant was enthusiastic about this kind of interaction: "Hand stroke with indicator was a perfect way of communicating problem / feelings without actually talking or looking at one another. Seems like a great new form of communication when one person is feeling things they can't express in words."

Thus the performance data suggest that some emotional information was communicated in our experimental context. As well, participants' report that their strategies were dynamic and comment that with an a priori strategy they would have been able to do the task. These observations suggest that mediated haptics as a means for emotional communication may be usable. On the other hand, only a limited amount of emotional information was successfully communicated in our study and some participants commented that it was a difficult task. These observations suggest that to be appropriate for emotional communication mediated haptics will require learning and co-ordination of strategies (unless such strategies become commonplace).

6.6 Remarks on Experiment Design

In this section, we discuss some considerations that would improve future iterations using this experiment approach.

6.6.1 Training for Dyad Haptic Models

One challenge when designing haptic models for dyads interaction is developing a mapping that people can understand. If the mapping is a direct connection, then it is not too difficult to understand how my actions affect you and vice versa; although even in this case it may not be obvious how much force you will feel in response to my actions. Indirect interactions are harder to explain and understand. We tried to mitigate this problem by using metaphors to design and explain our interaction models. However, during initial pilots people still had trouble understanding how their actions affected the interaction since what they felt depended on their partner's actions as well as their own. To enable participants on our study to develop an accurate mental model of the interaction, we presented them with both a haptic and visual representation of the interaction during initial training.

This strategy generally seemed to help participants understand how the interaction worked. However, there are two drawbacks to this approach. One drawback, in this situation, is that the visual feedback tends to draw attention away from the haptic cues. Different people will be more or less successful at directing their attention to the haptics; people who have a harder time at paying attention to the haptics may find themselves lost when the visual feedback is no longer there. Therefore, we asked participants to close their eyes at various points, during training, to concentrate on the haptics. The second drawback is that people may develop strategies for communicating emotion that are more appropriate for the haptic-plus-vision interaction than for the haptic-only interaction.

When asked what they thought about the interaction with visuals versus without visuals, most participants reported that it was more difficult without the visuals, especially with the ping pong metaphor. Two participants indicated that it was more interesting, fun or interactive without the visuals.

Despite its drawback, presenting a visual representation of the interaction seems to work as a way to help people initially understand the interaction, since they can see what their partner was doing as well as see and feel their own actions and at the same time feel the haptic output this generates.

6.6.2 Motivation

One factor that can influence performance during an experiment is motivation. In a communicating emotions task, there is stronger motivation for couples to do well than strangers. A couple has a vested interest in being able to communicate with one another that strangers do not share. Since using a mediated haptic device for communicating emotion is new, couples who have trouble with the task are likely to blame the device. However, being able to successfully use such a new interaction could be seen as an indication of a strong connection and thus a motivation for some couples that strangers are unlikely to have. We are not sure what effect this difference in motivation may have had on our results, but it is a factor that should be considered in design of future studies.

6.7 Summary

In this chapter, we discussed the meanings and implications of our experimental results and observations. We briefly summarize the main findings below.

In Section 6.1, we discussed the role of our control factors in computer-mediated haptic dyad interaction. Metaphor, space and relationship were all found to play some role in this type of interaction:

1. The *metaphor* used to design and explain a haptic interaction model influences
   (a) *Performance* on an emotion communication task,
   (b) *Subjective experience* of interaction
2. In a virtual haptic interaction space a *haptic indicator of personal space*
   (a) is *Desirable* from a subjective point-of-view
   (b) *Increases the complexity* of the interaction
3. The *relationship* of the pair engaged in interacting through a haptic device influences
   (a) *subjective experience* of a haptic interaction *metaphor*
   (b) *knowledge of partner's communication strategies*, in other media, which may *help or hinder* communication in the new media

In Section 6.2, we argue that there are common strategies for communicating emotion even in the new medium of computer-mediated haptic interaction. Furthermore, using these strategies to convey emotion leads to greater success. We suggest that if a pair used this medium to communicate frequently with each other, they may develop more unique yet effective strategies overtime.

In Section 6.3, the idea of an interaction model having an expressive capacity is presented. The expressive capacity of an interaction influences how difficult it is to learn and use. If the expressive capacity of an interaction model does not match that required by a communication task, it may be difficult to accomplish the task. Greater expressive capacity may complicate a simple communication task by increasing the number of possible ways of expressing a concept. However, this greater expressive capacity may still be preferred if it can be gradually incorporated into the interaction, thus allowing a greater variety of concepts or more complex concepts to be expressed.

In Section 6.4, we explore how real-world interaction influences interaction in the virtual haptic interaction space. In particular, communication strategies from face-to-face interaction are used in the virtual haptic interaction. This is seen both in the common strategies and in the use of intimate knowledge of their partner's face-to-face communication strategies by some couples. Also, in computer-mediated interaction the type of interaction that is preferred and more comfortable depends on the relationship of those engaged in the interaction.

In Section 6.5, the appropriateness of computer-mediated haptic interaction for communicating emotion is discussed. Results suggest that a connection can be created, and some emotional information can be communicate through our computer-mediated haptic interaction models. Overall, results suggest that an appropriately designed interaction used in context could be a successful medium for communicating emotion.

Finally in Section 6.6, we evaluate the use of a visual representation, and suggest that it is a useful technique to aid users in forming an accurate mental model of the haptic interaction. We also point out that, in experiments with pairs, the type of relationship between the pair may influence their level of motivation to successfully complete the task and this should be considered in experiment design.

Chapter 7

Conclusion

In this thesis, we presented work done to further understanding of designing for computer mediated person-to-person haptic interaction. Specifically, we discussed the interaction models and experiment we designed to test the effect of haptic metaphor, haptic support for awareness of personal space and the relationship of those using the interaction on performance and subjective experience during a communicating emotions task. We then set out the results we obtained from this experiment and discussed the meaning and implications of these results. In this chapter, we summarize the contributions of this work and suggest directions for future work.

7.1 Contributions

Creation of Effective Interaction Using metaphors and two simple one-degree-of-freedom haptic devices we were able to create effective haptic interaction models for computer-mediated haptics communication of cognitive emotion. Even though this is a new interaction medium and the only communication was though the haptic interaction, participants were still able to communicate considerable emotional content. As well, a strong sense of connectivity was created for some participants.

Systematic Analysis We designed and ran an experiment as a first approximation test of the emotional expressiveness of a haptic interaction model. To our knowledge, this is the first time a formal evaluation has been performed on the use of a haptic device to facilitate communication of affect between people. Our methodology enables quantitative analysis of performance, and also allows users to give an informed subjective comparison of multiple interactions after having performed an emotional communications task. It provides a means of evaluating the importance of different aspects of haptic interaction design, and of comparing different versions of key components of interaction design.

Metaphor We designed and tested four interaction models based on two metaphors and two levels of support for haptic awareness of personal space: no support, support using a haptic vibration. Another approach to design is to create a new interaction without a metaphor associating it to real-world interaction; however, using metaphors can help users to develop a mental model of the interaction. We found that the interaction metaphor significantly affects performance and subjective performance on a emotion communication task. The metaphor also affects other aspects of the subjective experience of using the haptic device. Thus, the choice of the metaphor used to design and explain a haptic interaction model is an essential design element for designing appropriate computer-mediated person-to-person haptic interactions.

Space A haptic indicator of space in a haptic interaction space is desirable. We found that users prefer and find a haptic indicator of space desirable even though it did not improve performance during a brief two hour interaction. Thus, if a haptic interaction model places users into a shared metaphorical space, an indicator of personal space should be present.

Relationship We found that the relationship of users of a computer mediated haptic communication device significantly affects the subjective experience of the users and needs to be considered when designing the interaction model. If a metaphor is used to design and explain the interaction model then it should be socially appropriate for the expected users. Specifically, the intimacy implied by the interaction metaphor should match the intimacy of the relationship between the users, or else discomfort can result.

Communication Strategies and Media People bring their strategies for communicating emotion in face-to-face situations into a virtual haptic interaction. Specifically, distance and speed in the virtual haptic space are commonly used in ways that are similar to how they are commonly used in real-world interactions. Common distinct strategies for each emotion are formed using these associations and should be supported in the haptic interaction model.

7.2 Future Work

Spatial Awareness We found that subjectively, users preferred our interactions with the haptic indicator of personal space. However, the haptic vibration we used did not improve performance across conditions. Thus one direction for future research is a more extensive exploration of how to provide spatial awareness to computer mediated haptic interaction spaces. The challenge is to create an indicator that is perceivable, understandable and yet does not overpower the rest of the interaction. Another possible research direction is to run longer term studies and explore how learning affects the use of a spatial indicator. A different direction is to explore multi-modal interactions that provide haptic interaction but utilize another modality to provide spatial awareness.

Designing for Relationship Given that the relationship between users of a computer mediated haptic interaction affects what type of haptic interaction model is appropriate, the next challenge is to design relationship-appropriate interactions. There are two research directions that result from this challenge. One is to design interactions that are not optimal for any one type of relationship, but are generally appropriate. The other approach is to take a particular relationship and design an interaction that is tailored to relationships of this type. Of course, this approach may be taken with any type of relationship including, but not limited to, the two used in our study. Some possible relationships are strangers, couples, parent-child, acquaintances, colleagues, and close friends. This approach is probably most interesting with relationships such as parent-child, and close friends. People who share these relationships may want to engage in remote touch interaction to communicate emotion, support or comfort, but the intimacy they share is not the same kind of intimacy as that shared by a romantic couple.

Field Study By doing a controlled experiment, we took the study of computer mediated haptic communication devices affective communication beyond the level of informal lab testing and demos. The next step in terms of understanding and evaluating computer mediated haptic communication devices is to design a haptic device and interaction model and then do a medium to long term field study. Such a study could explore several questions. The most basic question is whether people would make use of such a device for communication. Another question is how people would use such a device. In particular, in what contexts would it be used and what kind of information/cues would it be used to convey. There are two major aspects that such a study would encompass: long-term use and natural context.

7.3 Final Words

A telephone is a device for supporting remote verbal communication. Haptics could provide a way to support remote nonverbal communication. A telephone works by encoding and decoding audio signals such that the output is a close approximation of the input. For haptic devices it is not obvious what a good encoding and decoding should look like. Many possibilities for input/output mappings and interactions are possible with computer mediated haptic interaction. In this thesis, we initiated a systematic exploration of some of the possibilities. We designed interactions based on metaphors of real world interactions. It is our hope that these explorations add to the knowledge about how to design remote haptic interactions. The overall goal of this research is to provide a building block that can eventually be used to create a useful and usable computer mediated remote haptic interaction that support meaningful interpersonal communication.

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Appendix A

Experiment Script

These are the instructions read to pairs during the experiment.

A.1 Instructions

Welcome.

In this study we are exploring using a haptic knob (point to knobs) to communicate emotion. This study is exploring various ways of interacting with someone using this type of device. Lets try one of these interactions. (Explain interaction metaphor and follow metaphor script.)

Ok. Now notice that there are 4 emotion keys on the keyboard in front of you. During the next part of the study you will be asked to use the interaction to convey these emotions. Afterwards you will be asked to fill in this table to indicate how you conveyed each emotion. Lets look at it now. (give questionnaire, read directions, ask if they have any questions, take away)

(start interaction again) Ok. Now notice that there are 4 emotion keys on the keyboard in front of you. During the next part of the study you will be asked to use the interaction to convey these emotions. For each emotion think about how you might do this and try it out. Please dont talk as you do this since we are trying to concentrate on the touch. (allow time for this) During the actual task I will turn off the visual representation and only the touch will be available for communicating emotion. Try your ideas for communicating the emotions again but this time try closing your eyes.

Now we will move on to the communicating emotions task. I will give each of you in turn a list of emotions to convey to the other. For the list of 5 emotions I give you now the interaction will be just as what weve used so far. You will be able to see and feel a representation of what you are doing. Next I will give you each in turn a list of 10 emotions to convey and for these there will be no visual representation so everything will be conveyed and received through touch. The purpose of these first 5 is to learn what the feels mean so concentrate on the feeling and try closing your eyes when you have a good idea of what is going on. (give list and talk to her/him) When prompted please hit the emotion key for the next emotion on the list. Please wait for the prompt to hit the emotion key. (talk to other) Your task is to figure out what emotion he/she is trying to convey using the device. When you think you know the emotion that he/she is trying to convey, hit the appropriate emotion key. (start interaction and give emotion list)

A.2 Interaction Metaphor Script

Ping Pong Metaphor explanation:

This interaction is based on the metaphor of a game of ping pong. With your knob you can move back and forth towards the net and hit a ball. You will be able to feel the ball hit you. Ill turn on the interaction now and then explain further. (turn on interaction) Feel the ball hitting you. Try moving forward when the ball hits you -this will speed the ball up. Try moving back as the ball hits you -this will slow the ball down. Now try doing the same thing with your eyes closed and concentrating on the feeling of the ball. Notice that if you stay still the ball slows down slightly. In the middle of the space there is a net. Represented on the screen by a white line. When you run into this line it is like hitting a wall. You (point to one) try running into the net and try to feel the difference from when the ball hits you. Now try with your eyes closed.

(Now say the same thing to the other)

Hand Stroke Metaphor explanation:

This interaction is based on the metaphor of a hands touching and rubbing across each other. With your knob you can move your hand around in the space. You will be able to feel the other person moving as well as yourself moving. Ill turn on the interaction now and then explain further. (turn on interaction) Try moving the hands back and forth across each other. Try going slowly. Going slowly creates a stronger feeling like pressing harder. Try going quickly. Going quickly feels more like brushing by. Now try the same thing with your eyes closed and concentrating on the feeling.

Space Indicator explanations:

We are now going to add an indicator of how far apart you are from each other to the interaction that we just tried. What this means is that there will be an additional haptic vibration that you feel. When you are close together (for hand stroke add but not touching) then the vibration will be stronger. As you get farther away it will get weaker. (for ping pong add note the strength of the vibration does not depend on how far from the net you are. It depends on how far from each other you are.)

Appendix B

Emotion Strategy Form

This is a copy of the form participants' used after each metaphor/space condition to indicate the strategy they used to communicate each emotion.

Instructions:

Please put an X in the boxes to indicate which actions you used to convey each emotion. For example: The Xs in the first column would mean that hit hard, move far away and move slowly were used to convey Jealous. Place as many Xs for each emotion as is necessary to explain what you did. If the same action was used for more than one emotion, put an X in that action row for each of the emotions for which it was used. If you used actions that are not in this table please add them to the bottom and put in Xs to show which emotions you used these other actions for.

	Jealous	Anger	Delighted	Relaxed	Unhappy
hold still					
move slowly					
move quickly					
hit gently					
hit hard					
move close					
move far away					
repeat an action					

Appendix C

Final Questionaire

This is the questionnaire given to each participant at the end of the experiment.

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Final Questionnaire


For each question please circle your response.


1. The interaction metaphor I enjoyed the most was


a) Ping Pong  Hand Stroke


b) With Without an indicator of how close we were


2. I preferred this interaction because
--------------------------------------------------------------
--------------------------------------------------------------
--------------------------------------------------------------


3. I felt most connected using the following metaphor


a) Ping Pong Hand Stroke


b) With Without an indicator of how close we were
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4. I felt most comfortable using the following metaphor

a) Ping Pong Hand Stroke

c) With Without an indicator of how close we were

5. It was easiest to convey emotion using the following metaphor

a) Ping Pong Hand Stroke

b) With Without an indicator of how close we were

6. It was easiest to perceive emotion using the following metaphor

a) Ping Pong Hand Stroke

b) With Without an indicator of how close we were

7. When you were the perceiver did you remain still or did you move in order to feel what was being conveyed?

Moved Stayed Still Depended on:

Interaction Emotion

8. When acting as the perceiver, did you find yourself expressing the same emotion as you believed the conveyor was expressing?

YES NO

9. Did you change your strategy for expressing emotions to be more like your partners strategy as you learned what they were doing?

YES NO

For each interaction please comment on what was good (i.e made it enjoyable, made it easier to convey/perceive emotion) about the interaction and what you would change.

10. Ping Pong without indicator of how close we were

Enjoyed: ____

Would change:____

----

11. Ping Pong with indicator of how close we were

Enjoyed: ____

Would change: ____

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12. Hand Stroke without indicator of how close we were

Enjoyed: ____

Would change: ____

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13. Hand Stroke with indicator of how close we were

Enjoyed: ____

Would change: ____

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14. How did you find interacting with only the haptic representation compared to interacting with the haptic and visual representations?

Other Comments:
