Augmented communication with haptic I/O in mobile devices

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Tiivistelmä — Referat — Abstract

Nonverbal communication is a very important part of face to face communication. Both explicit and implicit additions to verbal communication augment the information content of communication. Before telephones did not provide any means for adding nonverbal information to the communication, but now, as the technology has advanced, it is possible to start augmenting also the communication on the phone.

Adding a haptic I/O device to a regular mobile phone opens possibilities to add value to communication. We conducted two user studies, one for exploring vibration as additional modality to the communication and one on how the contextual issues affect the pressure and behavior. These studies help to understand how the communication could be augmented and whether there is tacit information about the phone usage that could be delivered as part of the communication. Both studies were field studies. Using vibration as additional modality was studied in a longitude study with couples, while contextual impact was studied as a comparison of the laboratory and field discussions.

We find that it is possible to add haptic devices to a mobile phone and create a bidirectional communication channel based on the pressure applied on the phone. When the pressure is mapped to a vibration, it offers a new way of messaging. In addition, we find that there are changes in phone usage even in static laboratory conditions, thus it is possible to collect information about pressure, posture and movement of a person and share it with the discussion partner.

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Contents

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This study could not have been done without all the participants, who volunteered for this study.

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About contributions

This thesis is written as part of the studies of User Interaction research group at the university of Helsinki. Therefore it is only correct to give credit where it is due.

On the technical aspects of my work, I have had a lot of help. Craig Stewart has been responsible for building the devices for both of the user studies conducted for this thesis. He also created all the software necessary for recording the data for the studies and also the software to analyze the results of the recordings.

Eve Hoggan already had a HEI-project running and the part of the project with the interviewing couples seemed appropriate to be used for thesis in the explicit communications part. The study had already been planned and started, my contributions begin from interviewing the couples.

For the implicit communication part, I created the study plan from the idea and with the guidance of Craig Stewart and Eve Hoggan. Craig Stewart provided the tools and guidelines and Eve Hoggan provided guidance and prices for the participants, which made it possible to have so many volunteers for the study. My contribution

was to arrange the sessions with the participants and collect the data so that the data would be as useful as possible for the whole team.

We found that we have a great opportunity to analyze effects of the weather on mobile phone usage as our facilities are on the same campus as the weather stations of the Finnish Meteorological Institute (FMI). Craig Stewart contacted FMI and received information on how to gather weather data from their research databases. The weather data is therefore collected by the sensors of the FMI.

As the data collected is also used for other purposes than only this thesis, analyzes were also discussed and formed with Eve Hoggan and Craig Stewart. They have slightly different points of view on the data, but I acknowledge their valuable input on the analyzes of the data.

1 Introduction

The telephone has been the same for a long time — a simple way of communicating. It only provides voice information. Technology has improved since the emergence of the telephone, and therefore there is a possibility to add more information to communication via the telephone.

In face-to-face communication we receive information in various forms. The different ways of sharing information can be classified into two categories: explicit and implicit communication. *Explicit communication* refers to intended and direct forms of communication, for example the words we use [CDCT+01]. Implicit communication refers to indirect communication, such as facial expressions and tone of voice [CDCT+01]. Explicit communication is easily transferred also to mobile situations while implicit communication is difficult to present in mobile situations as it includes indirect clues such as body reactions and postures. Implicit messages can even be to some extent unintentional, as sometimes one does not pay attention to the signals one's body is sending.

These two forms of communication – explicit and implicit – are the core of this thesis. Our aim was to investigate whether traditional phone conversations can be augmented with features of face-to-face communication.

As the telephone has developed, it has more possibilities for gathering information. The first additions made to the phone were text messages and the possibility to send pictures. Nowadays the new telephone models also have a vibration motor,

and thus we are able to feel the messages coming to a phone as well. At the moment the biggest trend is touch screens, which enable communicating with the phone using one's fingertips. Maybe would be possible to send the touch to our partner in some form and so add more value to the communication.

The skin is our biggest organ. In addition, it is sensitive and capable of feeling different sensations such as pressure, temperature and mass. *Cutaneous*, or skin-based sense is therefore an important way of delivering information [vECA06, JRLS08, BB04]. The cutaneous sense can be combined with other senses to gain multimodal sensations and messages. The perception of *haptic*, touch based, messages can augment any communication.

Adding haptic elements to the telephone could also help special groups such as the deaf and the blind. Nowadays not many devices can be used by these groups as the devices often rely on visual and audio clues [BBP05, COJ+02]. If standard commercial phones could be augmented by means for haptic communication, this would also make the forms of new media accessible for people with special needs.

The revolution of touch screens opened plenty of possibilities for communications. It could be possible to caress the hand of one's partner gently or nudge one's partner on the cheek when located in a situation that it is not suitable to talk about everything. For example in public places it may be embarrassing to discuss about personal life problems. Non-verbal messages could be sent even in these situations, if the phone could deliver touch. We conducted a study with long distance couples, where they had a mobile phone with pressure sensor, so that they could squeeze the phone to send vibrations as messages to their partner. We aimed to find whether touch is suitable for telephones and whether it would provide additional value to the conversation.

The second part of this thesis focuses on inadvertent interaction. It is important to know what kind of issues affect communication and how people use mobile devices. We were interested in what happens when people are talking on the phone. It is likely that there are some changes in the interaction with the phone during the phone call. To find out what affects mobile communication, we conducted a study about implicit communication. In the study, we attempted to find how people interact with the phone and whether it affects the call if the person is moving outside in changing surroundings rather than sitting inside. If the surrounding world has an influence on the call and on one's interaction with the phone, the information about the changes could be shared with the discussion partner. This could augment communication

by providing more information on the situation and the other person's mood.

The aim of this thesis is to find new ways of using mobile phones for communication but also to find what affects the phone usage in general. When these parameters are clear, they can be harnessed to the communicational use. This thesis tries to answer the following questions:

1. How to expand the modalities of both input and output in mobile communication?

   The first study in chapter 3 focuses on this aspect considering both an additional output modality through vibro-tactile output and input through pressure. In the study we mapped pressure to vibration and used it as a new modality. When creating a new modality, it is important to eliminate disturbance of the signal. Therefore we continued the study with the following question:

2. What kind of impact does inadvertent interaction and other contextual factors have on mobile input such as pressure?

   The second study in chapter 4 focuses on the changes in the mobile communication and how the contextual issues affect the phone usage, such as the grip.

The structure of this thesis is as follows. Chapter 2 describes previous studies and how they affect this thesis. Chapter 3 discusses explicit communication with tactile expressions. Chapter 4 concentrates on implicit communication with mobile devices. Chapters 3 and 4 are both based on user studies. Chapter 5 describes the findings of both studies and discusses the possibilities of future work. Chapter 6 concludes the work.

2 Related Work

In this chapter we present related work on which this study is based. These studies are categorized based on how they provide background information for this thesis. First it is important to understand the meaning of the sense of touch and nonverbal communication to human interactions.

Second, it is important to know whether tactile messages can be recognized in general. If it is hard or impossible to distinguish messages from each other, there is no

use to communicate in this manner.

Third, as the previous studies have proven that tactile messages can be recognized, it is interesting to see for what purposes these messages have already been used. It gives us guidelines and ideas on where to continue next.

In previous studies many different kinds of devices have been used. Each device has its own advantages and disadvantages. In section refdevices we will take a look on these devices.

Section 2.6 takes a quick look at the methodologies used in mobile settings. The studies done on the field have different kinds of requirements than laboratory studies, and this is the reason why it is important to pay attention to the execution of the study as well.

As we are looking to find new forms of communication, there are several points of view that have not been extensively studied. The last section of this chapter discusses some of these points of view and describes necessary future work.

2.1 The sense of touch

The sense of touch is one of our most important senses. Our skin, muscles and other receptors react to the stimuli on our body parts [vECA06, BB04]. The receptors deliver information for example about size, resistance, pressure and roughness on us. As the skin is our biggest organ, the possibilities to of *cutaneous* (skin-based) perception are great but still not widely used [BB04].

Without the sense of touch, it would be impossible to create a complete view of the world. Most of our reflexes are bound to the sense of touch [vECA06], and without these reflexes it is very difficult for example to learn to walk. Even if visual and audio stimuli seem more important to us especially in adulthood, babies first learn everything based on touch. The very first sense we develop at the embryo stage is the sense of touch [vECA06].

The sense of touch is used to interact with objects but also to interact with other people [vECA06]. For example, we recognize the object we are looking for in the dark based on the touch of our fingertips. Different greetings like handshake or kissing are based on touch, but also slapping as a punishment or sexual intercourse most definitely involve tactile messages between us.

Especially for blind people, the auditory channel can be too overloaded with different

information [JRLS08, BB04]. But also for people with normal sight, using a mobile phone or other device with a small screen limits visual clues and if the surroundings are noisy, auditory clues lose their value as well [HB07]. Thus the sense of touch provides the best possibilities to deliver information.

2.2 Nonverbal communication

The importance of nonverbal communications seems to be somewhat underestimated in the mobile communication. There are several psychological an communicational studies that present that verbal communication is actually only a tiny part of overall communication. 7% of communication is based on talking, while 55% of the meaning of the message comes from postures and other nonverbal clues, and the remaining 38% concerns the voice quality, for example intonation and tone of voice [SH04].

The voice quality or *verbalization* consists for example of length of the communication, volume, intonation, *speech rate* and *speech error rate* [Meh68, CDCT+01]. Speech rate means how many words there are during some predefined time and speech error rate means how many errors there are during some predefined time period. All these are present also in the mobile communication, but the phone and the connection can alter them and therefore affect communication. There are no studies on how much people pay attention to verbalization aspects during a phone call, and whether the phone distorts the communication.

The nonverbal communication is an important communication channel. Of course, nonverbal and verbal communication channels are not separated from each other [CDCT+01]. Nonverbal communication reveals for example if the sentence was meant as serious message, as a joke or as a provocation.

Nonverbal communication can be categorized for example in immediacy cues, relaxation cues, movements and facial expressions [Meh68]. Immediacy cues signal the proximity between the persons but also the level of interest in the message. For example touch, eye contact and leaning forward are considered as positive cues of closeness and interest [Meh68].

Relaxation cues can communicate some moods and whether the other person is comfortable in the situation [Meh68]. For example position of arms, legs and head can point out that the person is enjoying the situation and is completely relaxed. On the other hand, when a person is crossing the arms, he or she seems impatient and stressed.

Movements of the body are also nonverbal communication. A simple nod of the head could signify that the person is listening and does not want to disturb the communication pointing it out verbally [Meh68]. On the other hand, twisting and changing positions or tapping on a table propose that the person is impatient and wants to get out of the situation soon.

Movements do not need to be big ones to be significant. Facial movements, such as raising an eyebrow are also important clues of perception [Meh68]. Also facial expressions, like a smile, give us information about the mood of the person.Then again, the facial expressions can get mixed, while the person is having strong, conflicting emotions. For example the expressions of the sadness and the anger are fusing when the person's beloved pet just got killed by a car[CDCT+01].

As nonverbal communication is clearly important in face-to-face communication, it could bring some additional value to indirect communication as well. Even if it is not possible to bring all the aspects of nonverbal communication into a telephone call, it is certain that some of them could be imported and benefited from. As at the moment we are missing more than half of the meaning of our messages, even small improvements could cause big changes in the way we communicate.

2.3 Recognizing tactile messages

In this chapter the focus is on previous studies [BK06, BBP05, KKL08, JRLS08, HB07] which have examined on the forms of recognizable *tactile messages*. Tactile messages are touch-based information. If different vibrations and other tactile signals cannot be recognized, it is of no use to try to deliver information with tactile sensations.

Tactons are structured messages or pieces of information that are delivered with sense of touch, in a sense iconic and simple touch language to be used on user interfaces [BB04, BBP06, HB07]. Even though the possibility for tactile communication in different devices is a quite new invention, *tactons*, also known as *tactile messages* or tactile icons, are widely used. For example texts for blind people – Braille texts – are based on the same idea [BBP05]. Braille texts are tiny cells rising from the paper or other similar surface, creating ridges that can be sensed with fingertips [BB04]. Tactons can be used to deliver information alone, but they can also be combined with other kinds of messages like audio and visual clues.

Vibro-tactile parameters are variables that can be modified to alter a haptic sensa-

tion. Basic vibro-tactile parameters are frequency, amplitude, waveform, rhythm, duration and body location [BBP05, BB04, BBP06]. Out of these, frequency is difficult to use as skin cannot feel a very wide range of frequencies, and in addition for the regular commercial devices it is hard to produce a frequency that humans could sense. Similarly, the amplitude is problematic, as users get annoyed if they cannot control the amplitude. A too small amplitude could stay unnoticed, and a too strong amplitude could cause pain. The duration is suitable for presenting different information but usually it is quite hard to know the exact duration of vibration, so it is better to combine the duration with something else.

In the study by Brown *et al.* [BBP05] the basic parameters were found inadequate,and thus more complex parameters were presented instead. These more complex parameters are rhythm and abstract labeling of the signal. *Rhythm* is created as combination of different vibrations. Rhythm is also important as it makes for example duration more clear.

Abstract labeling is used to group and compare different signals. In music it could be recognized as the instrument or the pitch of the voice. Brown *et al.* [BBP05] consider *roughness* as a label of this kind in tactons. People are able to say whether a signal was rougher than another signal. In the study Brown *et al.* were able to find three levels of amplitude modulation that people were able to separate from each other, describing them as smooth, rough and very rough.

The roughness seemed to be a good parameter for the tactile messages [BBP05]. Also when the roughness is combined with different parameters such as rhythm, the messages can become even clearer when tested on recognizing roughness levels and rhythm, the participants got both two parameters right in 71% of the cases. In partial recognition of the tactons, meaning that the participants got only roughness or rhythm correct, the rate is even higher. This suggests that when the parameters are chosen correctly, the differences between different messages are quite clear.

Brown and Kaaresoja [BK06] conducted a similar study using regular mobile phones where Brown *et al.* [BBP05] used special vibro-tactile devices. Brown and Kaaresoja considered that roughness could be also replaced with intensity. With a regular mobile phone the overall recognition rate of tactons including roughness was 52%. When intensity was measured instead of roughness, the results showed a 72% recognition.

Brown *et al.* [BBP06] studied whether the number of parameters in tactons could be augmented, as in previous studies there were only two dimensions of information

used. They added spatial location as a new parameter. The location works well as a parameter as long as the locations of the tactons on the body are carefully chosen so that some nerve reference points are met to make the feeling accurate. Brown *et al.* used three levels of rhythm, two levels of roughness and three levels of spatial location to create 18 different messages. Brown *et al.* found out that when presenting 18 different contents in three dimensions of variables, the overall recognition rate was 81%.

Jokiniemi *et al.* [JRLS08] tested how well rhythm was recognized as the same or different on *cross modal stimuli*. Cross modal stimuli is a combination of different forms of information, for example audio and haptic messages, to inform about the same thing. Jokiniemi *et al.* used auditory, visual and tactile stimuli and all combinations of these. The team found that recognition of the rhythm from a presentation as visual signal was considered unpleasant and difficult. While audio signals were the easiest to recognize, tactile messages were slightly more pleasant, though the difference was not statistically significant.

The recognition of the stimuli is not the only aspect of the vibro-tactile feedback. People are also capable of classifying different kinds of vibro-tactile messages based on their pleasantness. Koskinen *et al.* [KKL08] used two kinds of tactile signals – piezoelectric and vibrations – to create the tactile message. They found that both very low and very high levels of these signals were mostly considered unpleasant. On the other hand, the variation was notable, meaning that the users should be able to choose the strength of the signal.

Koskinen *et al.* [KKL08] compared the best signal forms from both piezoelectric and vibration signal groups against each other, and they also compared both signals against non-tactile feedback. The results showed that the participants preferred to have some tactile feedback while pressing buttons. The piezoelectric signals were considered slightly more pleasant than vibrations, but also vibrations were considered better than no feedback at all. Both methods also improved the efficiency and accuracy of the tasks given in the examination.

Hoggan and Brewster [HB07] studied the recognition of the crossmodal icons. In their study the participants were training to recognize the audio and tactile informations so that a half of the participants trained with the same modality, audio or tactile, that they had do recognize later on the actual test and the other half trained with the other modality to recognize the second modality on the actual test. For audio information the participants learned to recognize fully or almost fully the

icons on average 2 training sessions. For the tactile icons it took average 3 training sessions to learn to recognize the information.

Hoggan and Brewster [HB07] found out that when the participants had trained with *earcons*, audio based icons, they recognized about 76.5% of the tactons presented in the test. When the participants had trained on tactons, they recognized approximately 85% of the earcons. In mobile circumstances the participants, who had trained only with earcons were able to recognize 71% of the tactons and the participants who trained on tactons where able to recognize 76% of the earcons.

These studies show that people are able to separate tactile messages from each other. The participants of these studies were also able to distinguish parameters of the tactile messages and say which messages felt pleasant. This opens a whole world of tactile messaging, as it is possible to encode different kinds of information in various parameters. This shows that tactile messages can be used as form of communication.

2.4 Usage of haptic messages

Previous studies have confirmed that tactons can be recognized. The second question is, how to use these messages and where those can be useful.

While studying whether tactons can be recognized, the Brown *et al.* [BBP05, BK06] also proposed one possible use for the tactons. They used the roughness of the signal to describe priority of the incoming message on a three level scale (low priority, normal, high priority and high priority). The rhythm of the tacton was used to signal the type of the message. The message type was also based on three different rhythms, so that the first one represented voice call, second presented simple text message and the third one was for multimedia messages.

Vibro-tactile messages can also be used as messages themselves, if the differences are clear enough. For example in noisy surroundings where a voice cannot be heard or where it is not polite to use voice, like in library, vibro-tactile messages can be helpful [BK06, HB07]. Also especially for the blind people there is often so much information on the auditory channel that it is hard to separate the pieces of information from the mass, and thus tactile messages can provide alternative way of delivering messages [JRLS08, BBP06].

Haptic, touch based clues, can improve the efficiency and usability of tactile devices. For example, Hoggan *et al.* [HBJ08] have studied haptic clues in the task of writing

with tactile devices. Almost all the popular new mobile phones are using only a touch screen instead of using a physical keyboard. The problem is that also the feeling of writing has changed, and people who are used to a normal keyboard do not even notice they are making mistakes.

Hoggan et al [HBJ08] used one phone with a physical keyboard, one with a soft keyboard without any haptic clues and one soft keyboard with haptic clues to point out when finger is on the button, when the finger of the user is pressing the button on the phone and when the finger has slipped off the button. They used regular commercial products, first with their standard vibration motors and then with external *actuators*. An actuator is an external device that creates messages.

For the physical keyboard Hoggan *et al.* [HBJ08] measured an accuracy of almost 89% while the touch screen soft keyboard without any haptic clues only managed to get an accuracy level of 68%. As expected, the touchscreen with haptic clues achieved between the two others with an accuracy level of about 81%. This indicates that with the haptic clues, the accuracy of the touchscreen soft keyboard the is approaching the accuracy of the physical keyboard and most definitely improves the accuracy of the touchscreen devices. When examining the time it took test subjects to write sentences, Hoggan *et al.* found that it was faster with tactile touch screens. When the the vibrations came from an external actuator and also the spatial location of the tactile messages was considered, it took even less time to finish the sentences.

Haptic clues can also be used for navigating. Williamson *et al.* [WRS$^+$10] created a navigation system for multiple users. The aim was to help people navigate around the city to find each other without revealing the actual location of the other people. The people received vibrations when they pointed the device to the direction of the meeting point that had been calculated from the group's locations. The team first simulated the route finding and then they tested it in the field. They found that in a real setting there were more obstacles than in the simulation, but the participants were anyhow able find the meeting point.

Chang *et al.* [COJ$^+$02] developed a special device, ComTouch for vibro-tactile communication. It combines audio and tactile data for communicational purposes. As the team started to plan the device, they noticed that in remote communication, the touch is not used very often between normal people. On the contrary, in the communication between the blind and the deaf-blind touch is crucial, but the devices made for blind people are usually extremely costly.

When designing the ComTouch, Chang *et al.* [COJ$^+$02] listed some functionalities

that they considered very important. The device needed to be bi-directional so that the people at both ends could use the signal, and asynchronous so that one could send and receive messages at the same time. The device also needed to be asymmetric so that the message is sent different body location than where the received message arrives. This way there is a smaller probability of mixing the input and output. Finally, the device needed to be continuous so that there are no breaks in the usage. Chang *et al.* [COJ+02] also considered situations in which tactile communivation would be especially important. They concluded that these situations include situations where privacy is required, situations where touch would augment other forms of information and the situations with special needs users.

In ComTouch trials Chang *et al.* [COJ+02] found that there is a correlation between the audio and the tactile data. The participants used the vibration messages to emphasize the content of their speech. Also, even when the participants were not aware of it, they used the vibration to indicate that it was their turn to talk. The third form of tactile communication found was mimicry. The participants echoed each others messages for example to show they were listening, and thus the vibro-tactile message replaced nods and other visual clues. When audio usage was limited, the participants encoded their messages with numbers and other similar symbols for example by sending three vibrations to signify the number three.

One classical study of this field is study of HandJive [FCAE98]. Fogg *et al.* wanted to develop a way of entertainment for people who are isolated in situations where it is not possible to use any voice output. During the study the team found out that people invent some small things to do; they fidget all the time. Also it became clear that even the most simple devices could provide a great amount of entertainment in isolated surroundings.

With the HandJive prototype Fogg *et al.* [FCAE98] found out that manipulating moving parts of the device and competing over the control inspired and entertained the users. Even with ready-made patterns to control the device, people are likely to invent their own patterns and usages for devices such as handJive. That is, users might use it also for purposes other than just entertainment.

Haptic clues improve significantly the writing efficiency and accuracy on touch screen devices. It is likely that tactile messages could improve also other forms of communication. Tactile messages can also be used as messages themselves. It is possible to encode meanings in the different parameters of vibro-tactile messages. Haptic clues can also be used to emphasize and highlight messages in a way that is similar to

gestures in face-to-face communication. In addition, Chang *et al.* [COJ+02] found out that the tactile messages were used to signal that the person wanted a turn to speak. Haptic clues can be used to improve communication, but they do not necessarily need to have any specific meaning. They can be used as form of entertainment as merely a form of entertainment as well.

2.5 Devices used for haptic messaging

In previous studies, there have been various kinds of devices used for tactile messages. For the most part the devices have been separate prototypes created only for the study, like ComTouch [COJ+02], HandJive [FCAE98] and FeelLight [SH04]. ComTouch is a flat device, on which the user's hand rests. In turn, ComTouch [COJ+02] is designed so that its functionalities could be used better if it was a pouch around a regular mobile phone. HandJive is a joystick-like remote control, that can be turned around in the hand.

In the study of Brown et al [BBP05] they used special *tactuators*. Tactuators are actuators that send tactile messages. These prototypes concentrate on the functionalities and the new possibilities of the new forms of communication. The problem of these prototypes is that they are not truly suited for use outside the laboratory. Such prototypes might also contain expensive components that cannot become widely used by the general public. The advantages of prototype devices are more delicate output and the possibility to divide and control the input with multiple sensors.

Using devices of everyday life, such as mobile phones, it is possible to bring the advantages of tactile communication closer to ordinary people. As the studies of Brown and Kaaresoja [BK06] and Hoggan *et al.* [HBJ08] show, a regular vibration motor in a commercial mobile phones is capable of producing tactile messages and also making typing with touch screen soft keyboards more accurate. Naturally, the output is not as delicate as in prototypes with expensive actuators, but it is usable and useful regardless.

This shows that in essence any personal communication device can be used for tactile messaging, and haptic clues could be efficiently used especially in mobile phones, handheld consoles and tablets. If the functionalities are first tested with suitable prototypes, they can be implemented in any regular device.

2.6 Methodologies in previous studies

Most of the studies on tactons and their use have been held in laboratory conditions, including several of the aforementioned works [BBP05, BK06, COJ+02]. Only Fogg *et al.* [FCAE98], Hoggan *et al.* [HBJ08] and Hoggan and Brewster [HB07] have included afield study portion into their work.

Hoggan and Brewster [HB07] tested the recognition of the crossmodal icons on the simulated mobility circumstances. Their participants walked on the treadmill while answering the test. The treadmill was used to achieve the similar workload than on walking, but it made it possible to control the speed of walking and other variables. The walking lowered slightly the recognition of the tactons and earcons, which means that the effect of the mobility needs to be considered on the studies.

Roto *et al.* [ROH+04] have conducted a field study with mobile devices. They present some points of view that need to be considered while conducting a field study with mobile devices. First, the devices should not bee too heavy nor too visible, to prevent the participants from focusing more on the devices than on the experiment itself. Second, especially if there are multiple moderators conducting the experiments, they should be trained carefully, so that the researchers do not affect the study any more than necessary.

Roto *et al.* [ROH+04] also recommend that automatic logging could and should be used for standard events. Changing variables should be eliminated, for example the study should be executed always at the same day and at the same time to eliminate the effect from the light conditions.

As field studies require quite a lot of resources, it is important to evaluate the study beforehand with various methods. Williamson *et al.* [WRS+10] used a simulation to estimate how users would choose their routes to find a meeting point as mentioned before. The participants received clues of direction to their hand held device in a city area to reach a common meeting point with their friends. If the surroundings of the real experiment are limited, this kind of simulation gives good estimations of the execution of the task, but when there are more variables to account for, the accuracy of the estimation decreases. City environments and field study situations change constantly, and thus pilot studies and simulations can only provide rough directions for the actual experiment.

It is important to plan the study and select and prepare the devices used with care with care, so that the participants are not uncomfortable because of unsuitable

devices. When experiments are conducted outside, the participants need to know beforehand that they need to prepare for weather conditions. In the plan and in the coding of the collected data the variables should be chosen so that the researcher is affecting the results as little as possible, for example it would be good to decide the conversation categories beforehand. In addition, there should always be place for the unexpected events, for example the coding of the information can include the possibility of multiple choice option "other".

2.7 What has not been studied?

It is surprising how little there are studies on mobile situations in the field of mobile devices and mobile communication. In four of the previous studies [HBJ08, FCAE98, ROH+04, HB07], there were also some tests executed in field conditions, but in most cases mobile devices are tested only in laboratory settings. In the study by Hoggan *et al.* [HBJ08] the participants were traveling by subway for the purpose of the study whether the vibrations were still recognizable in a shaking carriage. But the participants did not themselves move during the study. On the other hand, in the study of Hoggan and Brewster [HB07] the participants were walking on a treadmill, but it is of course different than walking in the snow or rocky road. The purpose of mobile phones is to release people from the limitations of wires and to be usable also when mobile. Therefore it is important to see how movement affects communication. When people are moving, they tire and become breathless and this can influence not only the content of the call but also the way in which they interact with the phone.

Most of the studies in this field are only short term studies. If a study is only short term study, the novelty of the device used always affects the situation. The results cannot automatically be generalized to situations where the product is used for a longer period of time.

Outside the conditions change constantly, and it affects how people move. Weather, topography and noise level for example are changing conditions. Changes in these conditions can affect communication on many levels: the contents, the mood of the person, the level of fatigue and also on the level of the interaction with the phone. There are no studies on these effects whatsoever. In general, there are some studies executed in field conditions, but they concentrate on the ability to complete a certain task while moving, instead of studying how the mobile situation affects the task.

There are as many ways of holding the phone as there are users. Still, there may be

patterns in how people interact with the phone. For example, if most test subject constantly change hands, this can signal a problem with the phone. It may heat up too much or it may be too heavy. People might even express their current feelings unconsciously. None of previous studies considered that the position of the phone could provide useful information.

3 Exploring vibration as an additional modality

Explicit communication is direct, definite communication [web98]. The most typical example of explicit communication is speech. The person speaking chooses the words to communicate to someone else and the listener receives the message directly. Of course misunderstandings can have a remarkable effect on communication, and thus it is not clear that the listener receives the message as intended.

Voice and the speech are not the only forms of explicit communication. For example patting someone on the shoulder for encouragement or a handshake can be considered explicit communication. Signs such as these are culturally coded; every one from the same culture knows that a handshake signals greeting and presenting oneself. These signs may not need verbal communication to accompany them as they give enough information on their own.

Explicit communication is open and usually quite clear. The content of the message is shared at least with all the participants of the communication. On some occasions, for instance, when talking on the phone on public places, also other people are able to obtain the message. Therefore, some *tacit methods* methods of explicit communication are needed. Tacit communication is non-verbal and silent communication. Tacit messages could also be send during meetings or in a library.

To improve the tacit communication in mobile circumstances, we conducted a study on *vibro-tactile* messages on mobile phones. In this study we are interested in especially tacit messages that can be communicated via vibration-based tactile sensations. With the phones the participants of this study could send a vibration to the recipient. These messages encoded with vibrations could contain some value for the people that cannot be physically in the same location, for example couples in long-distance relationships. Thus, vibration is an additional modality of explicit communication.

3.1 Study outline

To study vibration as an additional modality with the mobile phone using other means than only the voice a longitude study was planned. For this study, three couples living in long-distance relationships were recruited as participants. The couples were asked to use a test phone for all the mutual calls for one month.

This study is part of the HEI-project, and thus it includes more aspects than merely explicit communication. The other points of view or shortly presented, but focus will be on using vibration as an additional modality.

In this study we had multiple aims and used multiple points of view. First of all, we aimed to find whether it is possible to augment a regular commercial mobile phone with pressure sensors and whether it would be possible to do it without significantly increasing the size of the device.

Second, we were interested in whether it would be possible to send haptic messages synchronously between two similar commercial mobile phones. The phones would need to be able to send and receive vibro-tactile messages, and the participants of the study would need to be able to feel the differences of local feedback of pressing the phone and the different levels of vibration received from the other participant.

From the technical point of view our hypotheses were:

1. It is possible to add a pressure sensor to a regular commercial phone without notably increasing the size of the device.

2. It is possible to establish a bidirectional communication channel based on pressure.

From the communications point of view we wanted to examine whether the sense of touch could be used, so that the vibrations could add value to the discussion. We assumed that the vibration could be used as way of expressing fondness, for example, to stroke the other person's hand. We also thought that *pressages*, the pressure messages, could be used in situations where it is not acceptable to behave emotionally, for example in public places. The vibrations could be shared silently and without drawing attention from outsiders.

The hypotheses for using vibration as an additional modality are the following:

1. Haptic messages can add value to a conversation.

2. Users can find different ways of using haptic messages.

This second part of the study concerned explicit communication and the user experiences. The couples talked on the phone with each other and sent vibrations as messages during the phone call to increase the value of the communication. As the study attempts to examine the use of tactile messages to express emotions, couples in relationships were chosen so that they would express their fondness and other feelings as naturally as possible.

There was no predefined meaning in the vibration messages, end thus the couples could decide themselves how to use the vibration. After every call they were asked to fill in a short questionnaire about the quality of the conversation. The phone calls were not recorded for privacy reasons – a couple can discuss even intimate issues on the phone, which means that the recording a conversation would change its whole nature.

3.2 Device

The device used in this study is Nokia n900 phone with the Maemo 5.1 operating system. The phone has a touchscreen and a physical QWERTY keyboard. The phones were usable as regular phones and the participants could use all the usual functionalities of the device, such as internet and the camera.

For the pressages, there was a supplementary a pressure sensor button in the upper left corner. The button was attached to a pressure sensing device located in the SD-card slot of the phone. For the pressages the standard vibration motor of the N900 is used. For protection of these supplementary devices there is also a rubber cover over the phone.

The vibrations are only sent when the user explicitly squeezes the phone. If the phone sent vibrations continuously, it would probably be too disturbing for the users. This also differentiates explicit and implicit communication.

The pressages are delivered between the phones as text over *Extensible Messaging and Presence Protocol (XMPP)* using a Jabber client. The phone receives the information in text format and then transforms it to the vibrations based on the detailed information.

The phone uses different channels for sending and receiving vibrations. This enables both phones to send and receive without being interrupted by the other person's

transmission. In addition, the communication with the vibro-tactile messages is synchronous with a timeout of five seconds. The timeout enables the user to feel the difference between the separate vibrations, but also to feel the local feedback from pressing the phone.

The prototype phone stores the duration of the call and the amount of vibration messages sent. Also the level of the vibrations is stored.

In the Figure 1 the devise is shown as it was for the users, with its protective cover, which also enables one to feel that he or she is actually squeezing the phone.

Figure 1: The device used in the experiments from the outside. From left to right: the bottom of the phone with a pressure sensor, the front, and the top of the phone.

In the Figure 2 the phone is shown without the silicon cover, so that the pressure sensor button is also visible. On the lower right corner the back cover of the phone is removed also, so that it is possible to see how the pressure controller fits in the SD-cardslot.

Figure 2: The device used in the tests from underneath the silicon covers. On the upper left corner the front of the phone, on the upper right corner the top of the phone with regular volume buttons and camera buttons, on the lower left corner the pressure measuring button and on the lower right corner the pressure device in the SD-cardslot.

3.3 Methodology

As mentioned above, three couples living in long-distance relationship were recruited for the study. In this case long distance means that the couple does not live together, they were not required to live in different cities. They used the phone for one month. Before the study they had a short lesson on the phone and its usage. As this study is relatively small and the device is a prototype, we consider it a pilot study with the purpose to find whether a more extensive study would be of interest.

During the first week of the study the couples used the device without the new features, so that it would be possible to compare their usual behavior and the behavior while using the vibration feature. After every phone call the participants answered a web questionnaire about the call. For the three final weeks of their test period, the participants also used the vibro-tactile messaging.

Ultimately, we had only two couples who were able to complete this pilot study. The participants of the first couple were both 28 years old, while those of the second couple were 21 and 26 years olf. Both couples consisted of one male and one female.

The participants were evaluated using the Myers-Briggs personality test [Que09, Typ], which is presented in appendix 6. The test categorizes the person under evaluation into personality types based on three scales: attitudes, functions and lifestyle. The first couple both were categorized as ENTJ-types. ENTJ stands for Extroverted iNtuitive Thinking Judging, meaning that the ENTJ-person likes to take control and act as an the example for the others [Typ].The second couple were categorized as ISTJ and ISFJ. ISTJ stands for Introverted Sensing Thinking Judging. An ISTJ-person likes to explore things and pays attention to details. ISFJ stands for Introverted Sensing Feeling Judging meaning that such a person is helpful and puts others before themself. An ISFJ-person wants to be useful and needed[Typ].

After the personality test and the guidance, the participants received the prototype phone for one month. For the first week they used the phone without the pressage features, so that it was possible to observe their usual habits in the phone usage. For the last three weeks they used also the pressage features the way they wanted. There was no predefined meaning nor were there instructions on when they should use it. They were only requested to fill in a short questionnaire after every call.

After one month of using the phone prototype the couples were interviewed together about their experiences and impressions. As the calls were not recorded, the couples were also questioned about the general topics of their discussions while they were using the vibro-tactile messages. The interviews were free discussions based on a list of questions. These questions are presented in appendix G.

3.4 Results

3.4.1 Technical results

From the technical point of view, this pilot study was quite successful. We found that it is possible to add a supplementary pressure sensor to a commercial phone without increasing the size of the phone substantially. The device was capable of sending and receiving vibration information when the users explicitly pressed the button. The phones did not need to be close to each other; they also functioned in normal call circumstances and even when the participants were 200 kilometers from each other. This means both technical hypotheses can be accepted.

on the other hand, there were also some technical problems. As the calls were made using Skype instead of normal phone calls, the functioning of the pressages depended

on how well Skype functioned. In 3G network the connection is not always stable enough to use Skype, which also caused problems. In further studies the phone could be more reliable if the functionality of the pressages was attached to regular phone calls.

3.4.2 Communicational results

From the communications point of view, there are several remarks to be made even though the number of participants was quite limited. The communicational hypotheses cannot be accepted as such, as the users themselves reported that they did not find the haptic messages to bring much additional value to the conversation and they did not use the vibrations for specific meaning. On the other hand, both couples were of the opinion that there are situations where the conditions in the hypotheses would be met and were able to give examples of such situation so the hypothesis did not prove entirely wrong either. The following studies should be continued in the direction suggested by these results.

The first couple used the pressages somewhat systematically. They did not have any specific meanings attached to different levels of the pressure, as they could not properly feel the differences during phone call. Nevertheless, they reported that they had used the pressages to greet each other in the beginning of the call and also to surprise each other. When one of them was talking too much and did not listen, the other could gain his or her attention by sending vibrations.

The second couple had technical problems with the device, and thus they ended up using the pressage mostly to only try it out. They did not sense the different levels of vibration during a phone call either. When the phone and the vibro-tactile messages functioned properly, the couple eperimented a little with the vibration.

Both couples considered that it was easier to express feelings with one's tone of the voice than with the pressages. The phone itself felt too big and uncomfortable, so pressing the button on purpose was quite difficult for the participants. Especially for the females it was difficult as they have small hands and they really needed to stretch their forefinger in an abnormal position to use the button. Partly because of the inconvenience caused by the phone, and partly because of the novelty of the pressages the couples did not find it a natural way to express themselves.

Both couples reported that it was annoying that when they started a call and wanted to send a vibration, one of the programs had already crashed, meaning that it was

impossible to send the pressage. Both phones need to have the program running in order for the pressages to work. The first couple usually restarted the call, if it was supposed to be more than merely a fast exchange of information. The second couple often considered it too laborious to reconnect every time the phone malfunctioned, and thus they woud most often merely talk without using the vibrations.

The second couple also reported other problems. Sometimes the vibration would not end even when the sender of the pressage had released the button. The phone occasionally also started to vibrate by itself, and the couple found it difficult to know whether the phone was functioning properly or not.

Both of the couples considered the vibrations uncomfortable at least on some level. The first couple reported that the vibration did not feel very good on the cheek and they considered it impolite to use the pressages. The vibration also stopped the conversation, as they usually had to ask each other whether the vibration had arrived or not.

The second couple also found that receiving vibrations distracted them from the conversation, but this was mostly because there was a buzzing sound before the actual vibration arrived. The sound revealed that a vibration would shortly arrive and stopped the conversation. Therefore, the pressages were not purely haptic message as they were intended.

3.4.3 Future usage

When directly asked whether the pressage feature could be useful, both couples were quite doubtful. On the other hand, the participants mentioned some interesting ideas how the vibro-tactile messages could be used. The first couple suggested, that pressages might be more interesting and usable if they were not mixed with the voice. The pressages would then serve as secret messages that does not require speaking or writing, but they would be "messages between secret agents". For example, short messages such as "I love you" or "I'm coming home" could be delivered this way.

The second couple also considered that the pressages could be used to show how much they cared of each other, so that long vibration would signal greater affection. On the other hand, the couple was worried about misunderstandings. If the phones did not function correctly, the recipient could get only a weak vibration and that could cause some arguments.

One of the participants also humorously suggested that it would be fun to give

electrical shocks to the partner. The first couple considered that if the vibration were used to express anger, the partner would also get angry because of the vibration, as the vibration interrupts the discussion and does not feel very comfortable. This would probably also happen with the electrical shocks.

3.5 Summary of the study

The study consisted of two long term trials with couples living in long distance relationships. The couples used a prototype phone with pressage features for one month sending vibrations to each other during phone calls.

Only information about the pressages was recorded, but the couples were interviewed at the end of the study. The interviews focused on the couple's user experience and their usage of the phone.

We found that the functionality of sending pressages could be interesting as a form of communication, but it should be usable also outside telephone conversations, so that the vibrations could be used as secret messages of their own. On the other hand, the usage of the vibrations was not intuitive enough, and especially as the prototype had problems, the first impression of the usage did not convince the users enough to make them desire the pressage functionality. Attention and effort were required when the pressages were used.

A study with only two couples is not enough to decide whether pressages would be useful or not. More studies need to be conducted, but this is only of value if the devices can be made more stable and trustworthy.

4 Exploring contextual factors influencing pressure and other behavior

Implicit communication is indirect, not specifically stated communication [web98]. For example, facial expressions, touch, posture and tone of voice can be classified as implicit communication. Usually some implicit communication is always present in face-to-face communication, which is the most natural way of communicating.

Implicit communication can be considered an addition to verbal communication, but on the other hand implicit clues can give us information even without words. For example, a person's posture gives us clues of his or her mood.

Implicit communication can be planned or unintentional. For example, people will show surprised face when they walk into a surprise party organized for them, or they can pretend to be surprised even though someone accidentally slipped the truth about the party beforehand.

When people use mobile phones or other devices for indirect communication, they lose most of the implicit communication. Only the pitch and the tone of the voice are present in a regular mobile conversation. Therefore, a mobile phone conversation contains substantially less information than face-to-face communication. Nevertheless, the implicit communication does not disappear as there is plenty of inadvertent interaction with he mobile phone. People only need to find means to communicate it.

In this section, we describe a pilot study on inadvertent interaction using mobile phones. In this study, our aim was twofold. First, we were interested, what kind of variables affect the communication either directly or indirectly, and second, whether there are any changes potentially meaningful to the discussion partner. If there were any changes, it could provide additional value to the conversation.

4.1 Study outline

In order to find the possible different forms of communication when using a mobile phone we conducted a study. The aim of this study was to reveal at least some of the issues that affect mobile communication. Our hypotheses are the following:

1. The personalities of the participants affect communication and the user's grip.
2. The weather affects the way people hold and use the phone.
3. The context affects communication and the grip on the phone.

Weather conditions change often, and therefore it is likely that when talking outside, also weather influences phone usage. But weather is not the only thing changing outside, also the surroundings can cause differences in mobile phone usage. Thus, we conducted the study in two parts: one part took place inside and the other outside. A conversation of about 20 minutes was had inside and about 20 minutes was had outside. Inside the participants were sitting in a quiet room, making themselves as comfortable as possible. In both parts of the study the phone was held as normally as possible, without any handsfree or other supplementary devices.

The phone call itself was not the only data recovered in the study. Before the interview, the participants first gave their consent for recording the call, and then they filled in their demographic information and a personality test, so that the participants could be classified according their personality. After the interview, all participants filled in two questionnaires, one on the quality of the conversation and a second one about their behavior during the conversation and their wishes on the implicit communication, for example what kind of information they would like to receive about the posture of the other person.

For this study 30 participants were required. As the main task in the study was to discuss on the telephone with a researcher, both friends of the researcher and strangers were recruited, because it is likely that friends behave differently during a discussion than complete strangers. Also an equal share of males and females was targeted. First our intention was to recruit 12 persons, but this number was considered too small for reliable statistics. In order to make the study more attractive and recruiting of participants easier, each participant was compensated with one movie ticket.

4.2 Device

The base for the device used in this part of the study is a standard Nokia N900 phone with the Maemo 5.1 operating system. It is a smartphone with a resistive touchscreen and a QWERTY-keyboard.

There are many kinds of information that the modern mobile phones can store. First of all, the voice can be recorded with standard recorder program that comes with the phone. It is possible to visualize the changes in the pitch of the voice. In addition, it is possible to see the pauses and the interruptions in the discussion.

Modern phones also contain a accelerometer. The accelerometer measures the position of the phone. Normally it is used, for example, to find whether the screen is used vertically or horizontally, but in this study we use it to find the changes in the position of the phone, for example, in which hand the phone is being held.

Using the internal gps-device of the phone, it is possible to track the location of the phone. With a preplanned route the gps helps to keep track of the participants location at the route at each moment.

The phone has been augmented by pressure sensor that registers the user's grip on the phone. The sensor is located on the side of the phone and covers the full length

and width of the phone. This disables the QWERTY-keyboard, but in this study, participants merely need to hold the phone and use it for speaking. In Figure 3 the phone of this study is presented with the protection covers removed and the attached pressure sensor visible.

Figure 3: The device used in these experiments without the covers. From left to right: the side of the phone with the pressure sensor, the front and the other side of the phone, without the pressure sensor.

The phone has a rubber cover to protect the additional devices. The cover also makes it clear that the phone should not be opened. In the test, there is no need for the keyboard as every program needed can be found on the desktop and they can be started using the touch screen. When the recording is started and the call is connected, there is no need to use even the screen; and in fait, the screen needs to be shut off so that it does not drain the battery. Figure 4 shows the phone as it was seen by the users.

Figure 4: The device used in the experiments from outside with the silicon cover, as the users saw it. From left to right: the side of the phone with pressure the sensor, the front and the other side of the phone.

4.3 Methodology

For the study, 30 participants were recruited, mostly using e-mails sent to different mailing lists. Personal messages were sent to friends. The people who volunteered

for the study filled in a questionnaire on their demographic information and chose a one-hour time slot for participating in the study.

For the outside part of the study, there was a predesigned route around the Kumpula campus area. The route had been selected so that there was variation in the grounds and surroundings. The route is in total 1.4 kilometers long. It has gentle downhills and some uphills, stairs up and down, sand roads and blacktop walkways. Part of the route is in peaceful surroundings, next to the botanical garden in Kumpula. The rest of the route is next to a busy road. Figure 5 presents the route.

Figure 5: The original route plan for the study

Both finnish and foreigners were wanted for the study as there might be some cultural differences in the way people use the telephone. As the study consists of conversations in the telephone, it was important to include both strangers and friends as the relationship of the participant and the researcher is likely to affect the quality of the conversation and the possible changes in the emotions expressed. Friends are more likely to express stronger feelings than strangers.

Most of the participants were Finnish with a total of 21 Finnish participants, and the rest represented 5 other nationalities, making the total 6 different nationalities. The

participants were aged between 22 and 38 years. The Figure 6 shows the distribution of ages among the participants.

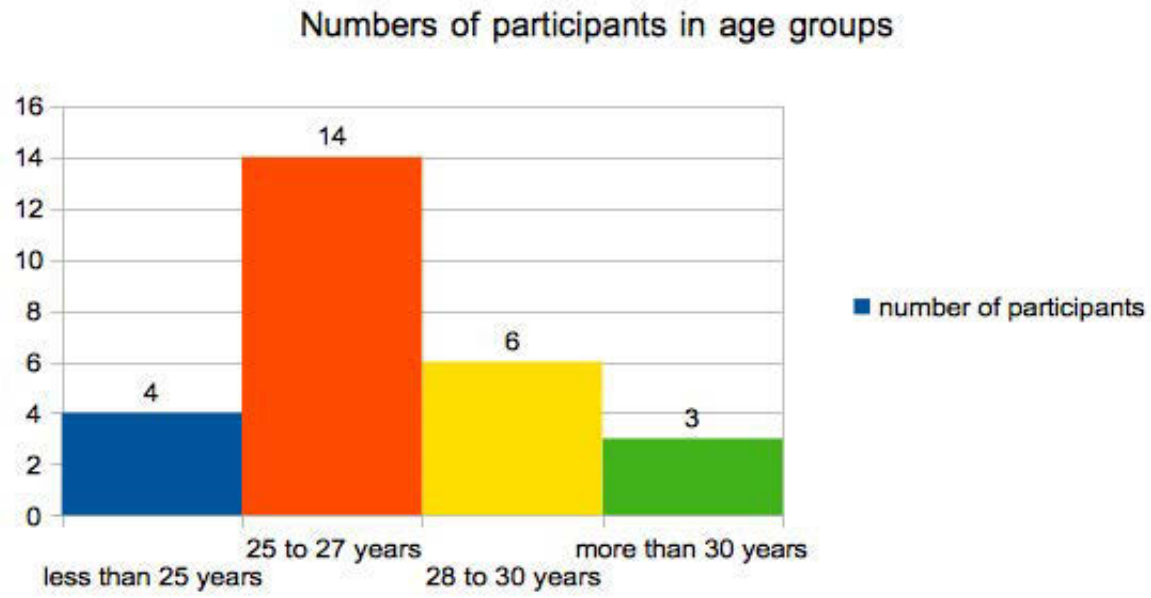

Figure 6: Distribution of ages among the study participants.

There were 15 females and 12 males in the study. Of the females, 9 were friends and 6 were strangers. Of the males, 5 were friends and the other 7 were strangers. Only one of the participants was left-handed and all the others were right handed. Most of the participants were students. The found professions are presented in the picture 7 .

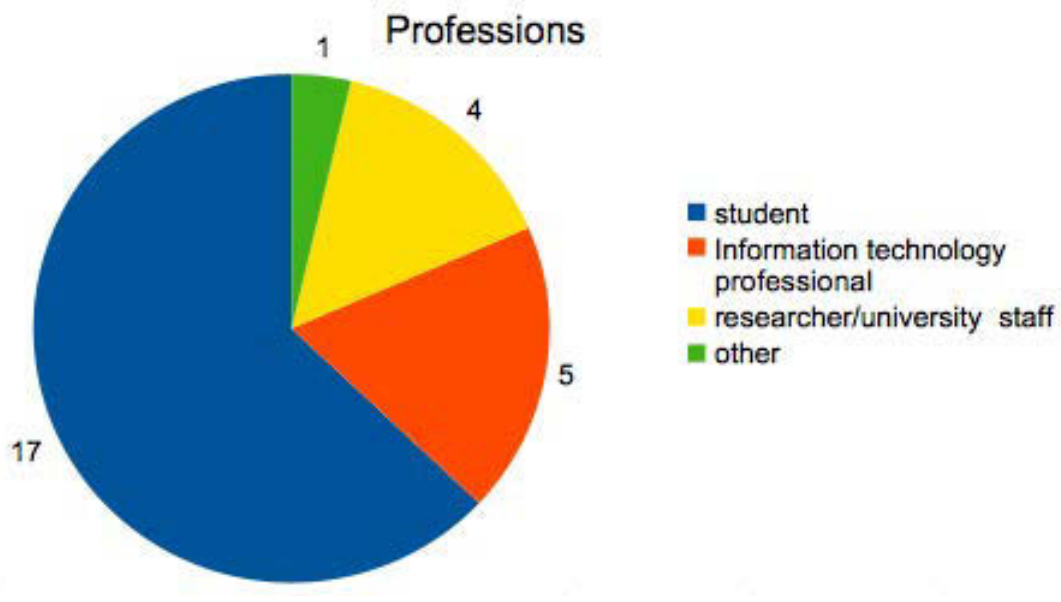

Figure 7: Distribution of professions among the study participants.

The conversation was free, but a list of topics was provided for the participants, so that they had the possibility to say whether there was something they especially wanted to discuss, or whether there was something they absolutely did not want to talk about. The free discussion is crucial to prevent awkwardness.

All the interviews were held between the 8th of November 2011 and the 16th of December 2011. Most often the whole interview was completed during the one hour. The participants first filled in a consent form and a personality test. Both the inside and outside parts of the interview took place after this. After the interviews, the participants filled in a questionnaire on the quality of the call and a small survey concerning the study and their wishes on implicit communication.

13 participants first took the outside part. Of these participants, 7 were friends and 6 were strangers. A total of 14 participants started inside from whom 7 were friends and 5 were strangers. In these numbers the retakes are not considered. If the retakes are considered, total 16 participants (9 friends and 7 strangers) started inside and 11 participants with 5 friends and 6 strangers started outside.

After the interviews, the participants also answered some questions about the quality of the call, that is the impression of the discussion, not the technical quality of the call. The questions asked about the call can be seen in appendix E. The questionnaire on the call quality may reveal some reasons for the participant's behavior

during the call, in case where there are some big changes in the data.

In addition, also some other questions were asked. These questions focuses on two things. First of all, the participants were asked whether they were aware of how they were holding the phone and second, whether they would be interested in new information about their discussion partners. The questions can be seen in the appendix F.

4.3.1 General issues that influenced the study

As the study is based on phone discussions, the real life conversations were simulated by the discussion with the researcher. This way it was possible to create a natural situation for the phone usage even if the discussion itself was artificial. We wanted the situation to be as natural as possible, but the participants being aware that they are being observed naturally affected the situation. While talking inside, the situation was more natural, as the participant and interviewer were not in same location. While walking outside, the researcher followed the participant and made observations. This made it possible to guide the participant in the right direction and to interfere directly if the connection was lost.

It is not only the participant's awareness of being studied that affects the study. The researcher influences the discussion in several ways. The researcher gives instructions to the participants on how to operate during the test, and these instructions affect participant's attitude towards the study. Also the chemistry between the participant and the researcher affects the conversation. To minimize these effects, the interviewer was the same in all the interviews. This means that the participants have similar instructions and the researcher has a similar attitude towards the participants.

Like in every study, some volunteers cancelled their participation before the interview. Within of the 30 persons who arrived to the study, one had to abort the interview. The inside part of the interview went well, but during the outside part the participant started to have severe pain in their back, and the test was discontinued ahead of time. The participant explained that draught causes them back ache every now and then. During the test the wind was quite strong and it was raining. Due to having to abort the outside interview, the data of participant 18 was discarded.

4.3.2 Technical issues that influenced the study

Due to technical problems with the test phone some interview data was lost. To replace the lost data, the participants whom the problem concerned were invited to retake the missing part of the interview, and they all kindly accepted. Thus, in a total four of cases, the two parts of the interview are not from the same day. In one case of the four retakes, it was the inside part that needed to be retaken, and in the other three the outside part was retaken. In addition, two other outside parts were retaken as the phone was still not recording properly, but the problem was noticed directly after the first try, and the retake occurred directly after the first attempt. One of these direct retakes was with a new participant and one with participant who came to retake the previous data crash. Even after two retakes outside, there were problems with the recordings of participant 1, and thus data for participant 1 was not used in the analysis.

The phone itself was not the only thing to have technical problems. The web survey used to collect data from the participants failed with one participant and the content disappeared. We contacted the participant but did not receive any reply, and thus the participant information only exists for 29 participants. Due to the missing personality test and after study questionnaires, the participant 12 was removed from the analysis.

The route on the outside part of the study had one problem as well. As at wintertime in Finland there is a limited amount of daylight and a small part of the route does not have any street lights, the dark, bumpy roads were a small safety risk. We did not want any accidents, so the route was slightly modified for the participants coming after sunset. Figure 8 presents the modified route. The length is basically the same as in the original route, and also the in the modified route there is the difference between the silent park side and the busy street. Only one uphill and one stairs down are missing from this route. A total or five participants took the modified route.

Figure 8: The modified routeplan for the study.

4.4 Results

4.4.1 General phone usage

In the demographic information collected for the study the participants were requested to estimate the usage of the phone in mobile situations, such as walking, driving or in public transportation. The answers are presented in Figure 9. The average amount of the mobile usage is 35.8% of the total usage (median 30.0%, standard deviation 23.9). The participants can be categorized into three groups based on their phone usage: uses only a small amount in mobile circumstances, uses average time in mobile circumstances and uses mostly in mobile circumstances. From the 27 participants, 12 use the phone only a small amount in mobile situations, 6 about the average amount and the remaining 9 mostly in the mobile situations. This means that more than half of the participants use the phone often or very often in mobile conditions.

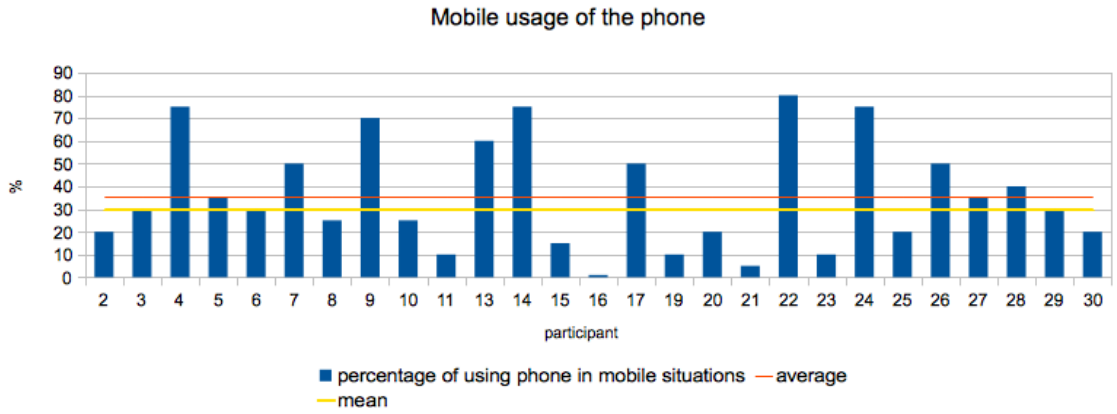

Figure 9: The percentage of mobile out of all phone usage for each participant.

75% of the participants reported that they used their dominant hand during the call in this study while 83% of the participants reported that they changed their hand during the call in this study. It seems that some of the participants did not consider that they used their dominant hand, if they were changing hands. In general, the participants were aware that they change positions during the phone call. In 16 answers out of the 25, the reason to change hands was that the hand became tired. Some also added that their ear got tired as well. In 8 answers, the hand being cold was mentioned as the reason to change hands. One participant indicated being stressed during the call, and one admitted that during the first call there had been discussion about and in the second discussion the participant started to think about it.

How ever, based on the accelerometer data, only 55% of the participants did actually change the hand even it was 83% that had said they changed hand. The difference in the hand changing percentages can be explained in a few ways. First, at least participant 24 changed the hand outside without changing the ear at the same time, meaning that the phone stayed in the same position all the time. For this participant, the data shows no hand changes. It is possible that some other participants changed hands the same way. Second, it is possible that some participants answered that they had changed hands if they assumed that is what we wanted to hear. Human behavior cannot be ruled out. Third, naturally it is also possible that there are some minor errors in the data set.

It seems that the participants believe that they know how they hold the phone, but the measurements do not support this. According to the measurements the users do not pay full attention to the grip on the phone and assume that they could have

changed hands even when they did not. On the other hand, constant hand changing can indicate that the user is stressed and impatient, or in the cold without gloves.

On average, the participants talked about 40% (standard deviation 0.03)of the time during the discussions. Inside the participants talked about 41% (standard deviation 0.03) of the call and outside they talked about 38% (standard deviation 0.02) of the total conversation time. The times were counted from the audio recording channels. There was one channel for the researcher and one channel for the participant, which meant that essentially, when one channel is silent, the other person is talking. Quite often, though the channels overlapped, meaning that the participant would be speaking at the same time as the researcher. Partly this is true, but partly the voices are just on both channels. Because of this, the estimation of the percentage of time when the participant talked is based on the time when the participant were talking and also on the time when both were talking. We assumed that the time when both channels were active, both the participant and the researcher had equal share of time, so the the percentage of the time was dived in two and the added for the total of the participant. In future studies it should be examined whether the pressure is different while the person is talking compared to while the person is listening.

The pressure levels on the pressure sensor of the phone vary greatly in both situations, as reported on [SHH+12]. Especially in the outside scenario there is a lot of variance. Because of the variance, the pressure is not a sufficient indicator to determine the suitable pressure level to be used in explicit messaging. To avoid unintentional triggering, the starting pressure level for explicit messages should be higher than the pressure level in normal phone usage. Figure 10 illustrates examples of the pressure variations inside and outside.

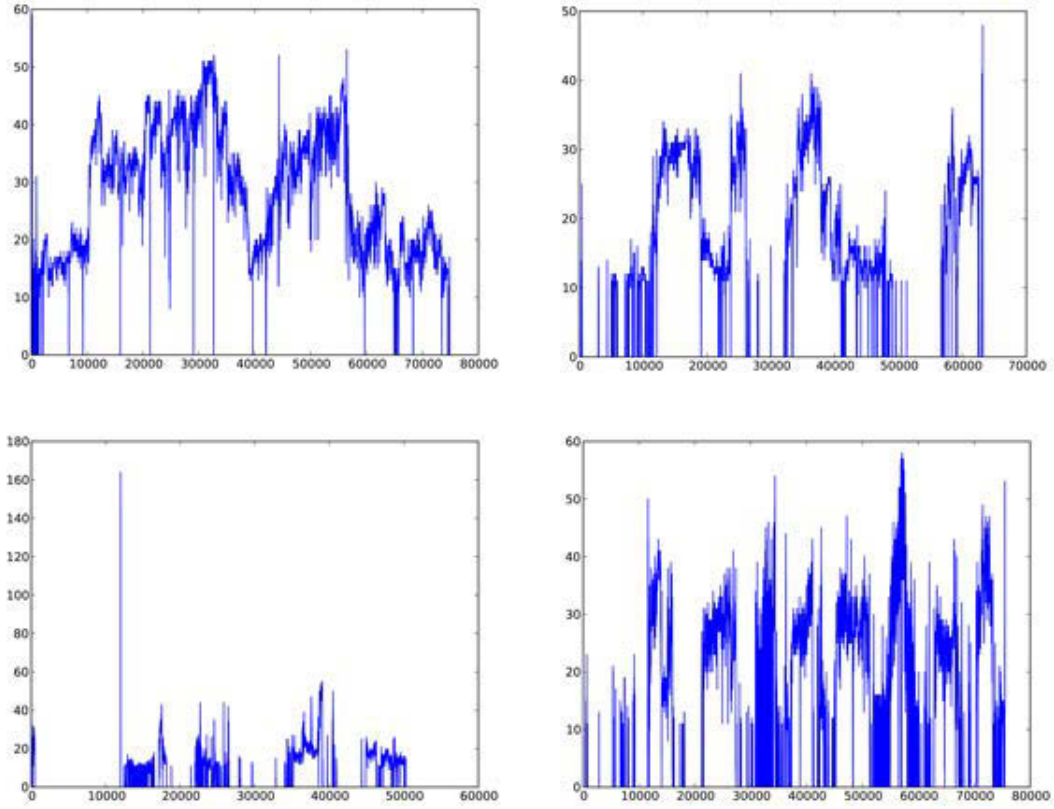

Figure 10: Illustration of the pressure variance. Examples from participant 4 indoors at top left and outdoors at top right, participant 30 indoors at bottom left and outdoors bottom at right.

As reported in the paper by Stewart *et al.* [SHH+12], the participants used significantly more force on the phone when they were walking outside than when sitting inside. Also the variance of the pressure was larger outdoors. The mean of the pressure and the variance of the pressure levels are presented in Figure 11.

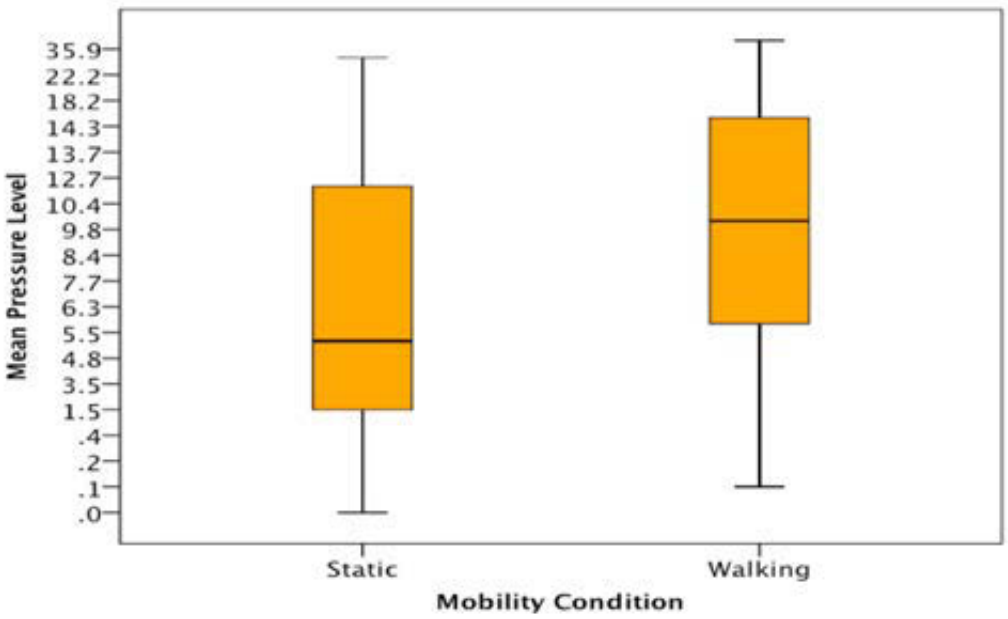

Figure 11: Average Pressure Levels for Static and Mobile Con- ditions (digitised sensor voltage 0 - 195 is mapped to voltage of 0 to 2.5v. approx. 0 – 3N) [SHH+12]

This indicates that a mobile situation affects the phone usage. Phones are used quite often when moving, as shown above, which means that it is important to note the inadvertent pressure on the phone can prevent a proper collection of the pressure data. Especially when the pressure is planned to be used as communication method, the implicit pressure on the phone could cause unintended messages. When the pressure levels are combined with accelerometer data, it is possible to explain some of the variance in the pressure [SHH+12]. For example, when the acceleration magnitude grows, also the pressure level rises. This means that movement in general increases the force applied to the phone.

There were no compulsory topics during the interviews. A list of general subjects was shown to the participants, to enable them to list possible topics that they did not wish to discuss. they were also allowed to tell the researcher if they did not want to continue with the current subject. Only one participant indicated that there was one subject the participant did not want to discuss, whereas the others were willing to talk about anything.

During the 20 minutes calls, the topics varied substantially. The average number of different topics during one session was approximately 17. For some reason, there

were usually more topics discussed outside than inside. 18 participants out of 27 discussed more topics outside than inside. The average number of topics were 16 inside (standard deviation 6.4) and 18 outside (standard deviation 6.0).

The number of topics was calculated so that whenever the discussion took a new direction, a new topic was considered to begin. After counting the topics were categorized. The topics were only added to one category even when they may have fit several categories. Because of the method of counting it was possible to have several topics from the same category during one discussion. It should be noted that the categories are subjective as is the counting of different topics and it would be possible to count and categorize the topics in other ways as well. Table 12 present how many times the topics on certain category were discussed.

topic	times discussed inside	times discussed outside	total times discussed
this study	15	53	**68**
university studies, student life	67	44	**111**
research	26	14	**40**
other jobs	26	11	**37**
tv-series and movies	12	5	**17**
route and scenery in Kumpula	1	52	**53**
events in personal life	11	18	**29**
cultures, differences in cultures and languages	32	28	**60**
travel	41	23	**64**
hobbies	23	23	**46**
climate (other than current weather)	21	26	**47**
current weather	0	23	**23**
phones	37	19	**56**
computers, games, other devices	28	16	**44**
food, eating, coffee breaks	24	22	**46**
other	82	89	**171**
TOTAL	**446**	**466**	**912**

Figure 12: The categorized topics discussed in the interviews.

In the category *this study* the participants were asking questions about the study, for example, how many participants were recruited and why this kind of study is important. It is natural that the participants were interested in the study, as they had volunteered for it. In these kinds of topics we tried not to reveal essential details about the study, so that it would not affect the results.

The two following categories, *university studies, student life* and *research*, were about studies and research at universities. As the majority of the participants were students or researchers at different universities, the related topics were easy to discuss, even with a stranger. Many comparisons between different fields of study

were made. And also favorite professors and courses were discussed.

The categories *other jobs* and *television series and movies* are quite clear. There was discussion for example on working at the post, as many students work during the summertime. For the *series and movies* category the main topics were the series and movies presented at cinemas or on television at the moment.

Route and scenery in Kumpula is related to this study. This category includes all the route instructions given to the participants, but also discussions on what was seen along the route. For example, the small cabins of allotment next to the route seemed to be interesting for the participants. Also the building of the Finnish Meteorological Institute was mentioned several times, as participants did not know the institute was located in Kumpula or what exactly is done at the institute.

The category *events in personal life* was mostly about weekend activities and about plans for Christmas, as at the time of the study Christmas was approaching. *Cultures, differences in cultures and languages* was especially popular with foreign participants, as they were interested in understanding some Finnish concepts. For example, many participants asked about the different Finnish words describing forms of snow. Also language skills discussions were considered part of this category.

In the *travel* category discussions were about places visited or places recommended, costs of traveling and so forth. In the *hobbies* category there were discussions different things that people had tried and that they would like to try.

The following two categories *climate* and *weather* are quite closely related. The difference between these categories is time. In the *weather* category were all discussion about the current weather. The *climate* category concentrates on general or future weather conditions, for example the amounts of snow during the previous winter or the differences between the seasons in Finland and in Asia.

In the *phone* category there are discussions about the test phone, phone usage in general, but also the new exciting models. The next category for *computers, games and other devices* includes the other technical discussion than about the phones. These two categories are separated, as the study was a mobile phone study, and thus it is likely to affect on the amount of discussion on phones.

In the *food, eating and coffee breaks* category the discussion was mostly about student restaurants and lunch. Also Finnish specialities were discussed.

The final category, *other*, includes everything else. The discussion varied from fire alarms to bumper stickers and from death penalties to people with the same name.

Most of these topics were discussed only once, and thus were not be categorized in a separate category.

The variation of the topics shows that context affects the communication at least on the level of direct communication. A mobile context increases the topics discussed in general. In addition, there were topics that were discussed notably more in one of the contexts. For example, the university studies were discussed 67 times inside in the university premises and 44 times outside, where the connection to the university is not so obvious. Naturally, the route instructions and the current weather were discussed only outside, except one notation of the route while inside.

4.4.2 Personality and phone usage

In the study, the participants filled in a personality test, which is available in appendix 6. The personality test is a short, 10-item version of the Big Five Inventory [RJ07].

The questions presenting related answers are combined with a mathematic formula, so that it is possible to present five personality traits, *extroversion*, *agreeableness*, *conscientiousness*, *neuroticism* and *openness*. These five traits have values between -5 (not at all) and 5 (very much). For example, value -4 in extroversion means strongly introvert person.

A person that scores high in extroversion can be described as talkative, assertive and energetic [JNS08, p105]. Agreeableness consists of good-natured, cooperative and trustful elements. A person who shores high in conscientiousness is orderly, responsible and dependable. High scores in Neuroticism can be considered as emotional stability. Emotionally stabile persons can be described as calm, not neurotic and not easily upset. The persons scoring high in openness, also called intellect category are often intellectual, imaginative and independent-minded.

Table 13 shows the results based on the participants' answers.

participant	Extroversion	Agreeableness	Conscientiousness	Neuroticism	Openness
2	3	4	4	−3	3
3	−3	1	0	1	4
4	0	2	1	3	−3
5	4	1	3	−4	0
6	3	2	0	0	1
7	4	3	2	0	0
8	−2	3	1	−2	0
9	3	2	1	−1	4
10	0	1	0	0	2
11	1	4	2	−2	−1
13	−3	3	0	3	0
14	1	2	−3	−1	1
15	2	3	0	0	0
16	2	3	0	−1	0
17	2	1	0	0	2
19	0	0	−2	−1	0
20	1	1	0	0	0
21	−2	3	1	2	−2
22	−1	2	−1	−2	−1
23	−4	0	3	2	1
24	2	1	0	0	−1
25	0	−1	1	0	0
26	−1	2	1	−1	0
27	−1	3	0	0	3
28	3	2	2	2	3
29	−2	−1	1	4	0
30	0	0	3	−2	3

Figure 13: The personality test results.

The correlation between the personality and the number of topics is interesting. The strongest correlation is with neuroticism. The correlation between neuroticism and the number of topics talked inside is -0.305 but it is not statistically significant. The correlation between neuroticism and the number of topics discussed outside is negatively strong, -0.444, and it is statistically significant (p=0.05).This means that the more neurotic the person is, the less he or she talks on different topics. Apparently the neurotic habits are stronger outside. The neurotic participants might even feel that they cannot control the situation as much as they would like to and thus they try to change topic more often.

If neuroticism explains partly the number of topics discussed outside, it also points back to the topics discussed inside. The correlation between topics discussed inside and topics discussed outside is very strong, 0.772 (p=0.01). Therefore, even if the correlation between neuroticism and topics discussed inside is not statistically sig-

nificant, there might still be some indirect influence, which needs more investigation.

The personality and the average pressure on the phone do not seem to correlate. There are some moderate correlations, but they are not statistically significant. The pressure on the phone does relate to the person though, as the pressure applied to the phone in indoors conditions correlates with the pressure applied in outdoors conditions strongly. The Pearson correlation is 0.657 (p=0.01). This means that no personality trait can be used to explain the pressure changes, but the participants have a typical way of using force over the phone.

These results show that personality does have some effect on the phone usage, but most certainly it is not the only thing explaining the behavior with the phone. Nevertheless, the hypothesis 1 — The personalities of the participants and their relationship between the participants affects the communication and phone usage. — can be partly accepted as there are some personality traits that seem to explain some of the variance in the dataset. To confirm these results, the effect of the personality should be evaluated again using a bigger sample of participants. The personality has a small effect on the usage of the phone, but we need to look at the other aspects of the variance as well.

4.4.3 Weather and the phone usage

During the interviews the weather conditions were somewhat unfortunate, as it stayed quite grey and humid throughout the test period. The average temperature of all interviews was 4.15 degrees centigrade and the standard deviation was 2.17. The average of 30 years in November is 1.4 degrees and in December −2.2 degrees [FMI].

With only one participant the temperature was below zero. The average relative humidity was 81.80% with standard deviation of 15.24. It rained during 17 outside sessions. Most of the times the rain was not strong, and it did not last for the whole interview. Some participants had some watery slush on the route, but mostly there was no snow. The average wind speed was 4.77 $^{m}/_{s}$ with a standard deviation of 2.33. The direction of the wind and the wind speed during the interviews are shown in Figure 14.

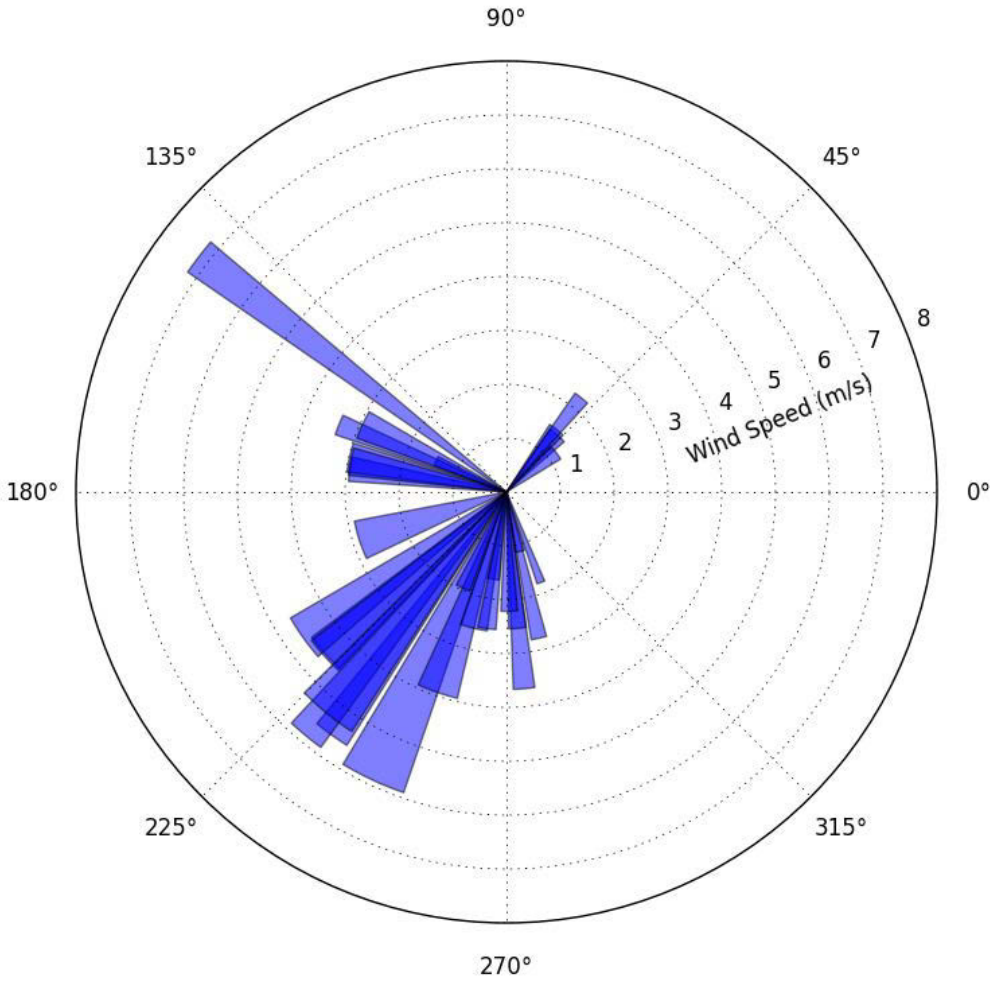

Figure 14: The wind speed and the wind direction during the interviews. The direction is relative to the weather station. The width of the pillar presents the duration of the gust and each pillar is presenting a separate interview.

In any case, the weather seems to be relevant to at least direct communication. When the weather was beautiful, there was not very much discussion about the weather. Sometimes it was mentioned, for example, that we have to enjoy the sunshine as long as it lasts, as the winter is going to be dark. But when the weather was not very nice, when it was windy and raining, the weather was brought up several times in a discussion.

The current weather was discussed 23 times in the outside conversations, but not even once in the indoors conversations. The climate and weather outside the current

moment were discussed inside 21 times and outside 26 times. It should be noted that the marks for weather conversation were not all from different conversations. but some participants brought up the weather several times. All the weather discussions were done with 14 participants out of 27. The weather was brought up several times by 5 out of these 14 participants. With all except one participant out of these 5 had both rain and quite strong wind during their interviews. The one remaining participant did not have rain but the participant had the strongest average wind speed of 10.66 $^{m}/_{s}$ and in gusts the windspeed rose up to 16.1 $^{m}/_{s}$. It is quite clear that the worse the weather was, the more the participants talked about it.

The weather data has one entry every minute, while the pressure sensor data is more irregular. It has sometimes several entries every second, and sometimes there are pauses of few seconds between the values. This problem relates to the usage of an external pressure sensor. Because of these differences in the data, the comparison of pressure and weather correlation is done with the mean values of both pressure and weather indicators.

There is a strong negative correlation, -0.441 between the relative humidity and the average pressure and it is statistically significant ($p=0.05$). This means that the more humid the weather is the less there is pressure on the phone.

As a clear correlation exists with only one factor of the weather, more analyses would be needed. Also, different kinds of weather conditions should be considered, as this study does not show how the humidity affects phone usage if it is very dry, for example on a extremely cold winter day, or the environment is tropical, where the air is humid but the temperature is high.

The correlation of humidity and pressure on the phone does not prove that the humidity causes changes in the pressure, but it does indicate that weather circumstances do affect phone usage somehow, either directly or indirectly. Also, at the level of communicational content the weather was indeed significant. Therefore our hypothesis 2 — The weather affects the way people hold and use the phone. — can be partially accepted.

4.4.4 Future usage of implicit information

In the post-interview questionnaire 17 participants indicated that they would be interested of having new information about their companions implicit messages. Most of them were be especially interested in the pressure on the phone, as it may indicate

some (mood) changes but also whether the time is suitable for a discussion. One participant specified that the position of the phone and the pressure may indicate that the companion is laying on the bed or is using the toilet or in other private place or situation, and it might be better to call back later. Another participant proposed that the pressure on the phone could be used to monitor how the companion is feeling that day. For example, when talking to an elderly person, if he or she does not have the force to hold the phone as tightly as normal, it may indicate a possible fatigue or illness.

Some of the participants who were not interested in this kind of information wanted to justify their opinion. They said that they are not comfortable with sharing this kind of information about themselves, sand thus they would not be willing to receive such information either. These participants said that they want to maintain some privacy during the call. One also specified that they preferred to imagine their companions in a neutral situation, such as sitting on the couch, rather than knowing where they actually are.

On the other hand, for those who were interested in understanding their partners behavior, there is some information that could be valuable for the conversation. The accelerometer can detect the gait of the person when the movement into different directions is combined. This reveals whether the person is walking around, hurrying to a bus or simply sitting somewhere. This could be used to partly replace the information about physical position and posture that is usually available in face-to-face communication.

4.5 Summary of the study

The inadvertent interaction study presented above was conducted to find what kind of factors affect a phone conversation and the usage of the phone. A large set of data was collected from various sensors to see if anything changes during a regular discussion. Data was collected in laboratory conditions to observe regular phone usage without any specific issues, such as movement and weather affecting it. For comparison, a field study was conducted to find whether surroundings and situations affect the communication.

The study consisted of 27 interview sessions in the Kumpula campus area. Each participant discussed with a researcher on the phone inside and outside. The calls were recorded and pressure, gps and accelerometer data was gathered. In addition,

weather data was received from Finnish Meteorological Institute.

The study revealed that the there are indeed changes in the data in both situations. When a person is walking outside while speaking on the phone, there is even bigger variance on the data. As the data is not static, it is possible to use it to inform discussion partner about the details of the location and position of the person.

5 Discussion of the results

5.1 Results concerning the general study questions

In this thesis there were two overall research questions:

1. How to expand the modalities of both input and output in mobile communication?
2. What kind of impact does inadvertent interaction and other contextual factors have on mobile input such as pressure?

Regarding the the first question, we find that it is possible to map a pressure input as an output of vibration. This opens new possibilities to add new modalities on mobile communication. The new modalities could be used to support voice, but also the new modalities can be separate and a truly new form of communication.

Second, context affects communication on the mobile phones, as it affects any other form of communication. Communication is different if the person using the mobile phone is under peaceful laboratory conditions or moving outside under the influence of weather and terrain. Part of the context is also how well the persons communicating know each other. With strangers communication is less natural.

Phone usage is not static. Inadvertent pressure on the phone is clearly different indoors and outdoors. Outdoors the average is higher and there is more variance. The three dimensional accelerometer data reveals if one changes hands during the call but it also defines together with the pressure whether the person is inside or outside, as outside there is more pressure on the phone and the gait reveals that the user is moving. Naturally, also the topics and gps location change during a call.Not all changes were studied in this work. For example, the verbalization could vary strongly.

Finally, it is clear that when the comprehension of emotions and expressing emotions implicitly on a mobile phone increases, all the changes such as pressure on the phone and the position of the phone can be used to add value to communication. This study opens the way for examining the details of mobile communication. As it is now clear that phone usage is not static, we can start examining what are the true reasons behind the variance in the data. For example, the anger may manifest itself as a stronger grip on the phone.

5.2 Combining explicit and implicit communication

Both explicit and implicit communication are important, and in an ideal situation they are combine d. For example, the implicit information may explain how the explicit message should be interpreted. Pressure is one form of information that could be used for both explicit and implicit communication in mobile phones.

It has been shown that it is possible to create a bidirectional synchronous communication channel without extremely expensive devices. The pressure on the phone can be transformed to vibration that the discussion partner can sense. The users of the phone can explicitly press a button to send messages. These messages could be predefined or freely definable messages between the discussion partners.

To be able to use the explicit pressages to communicate, the natural inadverent pressure on the phone needs to be considered first. If the normal pressure level is not considered, this can cause an excessive amount of accidental triggering of pressages. This disturbs the communication and feels uncomfortable. To avoid accidental triggering, the explicit pressure levels should be stronger than the implicit pressure on the phone.

We find, as reported in the conference paper by Stewart *et al.* [SHH+12] that while walking outside the inadvertent pressure is stronger than sitting inside in the laboratory. Some other variables such as mean magnitude of acceleration augmented the information received from the pressure level on the phone. When the variance and the variables affecting it are taken in to account, we find that the inadvertent pressure rises up to 0.6N, which is about 20% of the pressure scale that the sensor provides. This way the remaining 80% can be used as desired for explicit communication with pressure.

As people do not simply the phone statically, the changes of pressure and other variables could provide valuable information for implicit communication. Especially

the accelerometer data could be used to describe the posture of the person. An accelerometer reveals which way the phone is held and together with the pressure, it predicts very accurately whether the person is walking or sitting.

When the two channels of communication, explicit and implicit, are combined, the communication becomes richer. Implicit communication provides hints how to interpret the message. For example, if a person wants to express his or her support for the partner in a difficult situation, he or she could explicitly say encouraging words and send a smooth vibration to simulate holding hands. In addition, the person's firm grip on the phone could indicate closeness and concentration on the topic.

5.3 Future work

Mobile phones are an effective means of communication, but mobile communication still misses plenty of information available in face-to-face communication. Our studies clearly show that the work with mobile phones is not finished. The ideas presented below are just some aspects that deserve further attention.

In our studies we only focused on speech communication and used other communication methods only to support the speech. As modern mobile phones are not merely telephones that are mobile, it is important to be aware how mobile situations affect other functionalities of the phone. For example, writing text messages, using the camera and the internet on the phone are more and more important in daily use. All these are functionalities that are used while moving meaning that weather conditions and forms of the ground can affect also the usage of these functionalities.

The device used in these studies was suitable for the studies, and it provided a lot of useful information. On the other hand, the prototype was considered too big and heavy in both studies, and the closed source software on most commercial phones limits studies such as this. Also, the phone needs to be big enough so that it is physically possible to attach supplementary devices to it. Nokia N900 provides a good possibility to continue the development, but it is not intended for regular phone users because of its size and rather complex usage. When research aims to find new functionalities and new ways of communication, the results are always questionable because the prototypes used tend to be completely different from existing regular devices. The results should be confirmed with a standard commercial phone that real end users would be likely to use.

In the implicit communication study we found some possibilities that could be used

to give information about the discussion partner. For example, data collected with an accelerometer could be used to give clues about the physical position of the person. In future studies it would be important to develop methods for sharing this information While speaking on the phone it is difficult to receive visual information, as the phone is at the persons ear, and the audio channel is occupied. Perhaps haptic clues could give information about the posture of the other person, but on the other hand this could be too complicated way to share such information.

The hands-free is a useful tool especially when the person is moving. It would be important to examine how the results would change if the phone was held in the hand like a remote controller and the talking would be done using a headset. Also, another interesting topic to examine would be whether the data still reveals the gait of the person.

Eventhough we wanted to study how weather affects the mobile phone usage,the weather conditions during the study were quite limited. During November and December 2011 the weather in Helsinki stayed fairly similar. It was grey, windy and raining on occasion, but there was no snow. Usually during the Finnish winter there is a substantial amount of snow. Snow storms would most likely affect communication and the gait. Also a colder temperature could affect the study but also the device. The study should thus be repeated in hard winter conditions.

Ths thesis is merely a first pilot study on how personality affects communication. Personality should be studied together with the verbalization aspects and holding the phone. Personality could explain some of the variance in the pressure or in the accelerometer data.

A mobile phone with a pressure sensor and accelerometer can predict the gait of a person quite exactly. It also reveals the walking speed and other pieces of information about the body movement. If the accuracy is sufficient, the mobile phone could also be used in medical studies. Physiotherapists and other medical professionals could measure the person's movement with a regular mobile phone instead of using extremely expensive special devices. These special devices cannot be given to the patient to take home but they can carry their own mobile phone. The continuous control of the movement might also replace some of the accuracy demand as the examination with the special device is done only once. There may also be other medical studies that could benefit from the information provided by regular mobile phone.

6 Conclusion

Telephone communication is quite poor in information when compared to face-to-face communication. Even though the voice provides more information than for example bare text, the call still lacks most parts of nonverbal communication. Nonverbal communication includes facial expressions, postures, verbalization and other implicit information. On the other hand, the voice is also the only form of explicit communication at the moment, and it is not always possible to use one's voice for example in a meeting or in a library, or for example in a concert it can be so noisy that it becomes impossible to hear the voice.

As the telephone technology has changed and plenty of new features have been introduced during the last few years, we wanted to find whether the communication could be augmented as well. We wanted to find what actually happens during a mobile telephone conversation, and if the information gathered in the study could be used to augment communication. In addition, we wanted to look for an alternative for the voice in explicit communication.

We conducted two separated user studies. The first study examined explicit communication with a squeezable phone, where by squeezing the phone the participant could send a vibration message to the other person. It the study, two couples not living together took part in a month-long study. They used the squeezable phones as their primary phones in their communication and reported on their experiences on sending vibrations to each other. The number of vibrations sent was recorded, but the calls were not, as this would have intruded the privacy of the participants.

We find that it is indeed technically possible to create a new, bi-directional communication channel that works together with the voice call. On the communicational side the study showed that there was a large amount of accidental triggering of pressages, and thus it was difficult to send meaningful, intentional messages. Partly due to that, the participants were not enthusiastic with the pressage functionality, but they were of the opinion that it could be more useful if it could be used without a voice call, like a secret messaging tool "for the secret agents".

The second study examined the implicit communication side. To improve implicit communication, we were interested in whether there are changes in the grip and posture of the person talking and if so, what kind of changes they are. 27 participants discussed on phone with a researcher for 20 minutes both inside in static laboratory conditions and outside in a mobile situation. The phones recorded the conversation,

the gps location, the pressure on the phone and the three-dimensional accelerometer data.

We find that the grip on the phone and the posture change constantly during the conversation, even in a static indoors situation, but especially outdoors. Outside there are several variables that affect the phone usage. For example, the terrain and the weather change constantly, and therefore the grip and the posture change as well. We also revealed some limitations for explicit communication, as the results showed that the grip changes inadvertently during the call.

In general, we find that it is possible to augment communication with haptic devices. The sense of touch can be added to the phone conversation with simple pressure sensors, and a accelerometer tells about the posture. Now that the possibilities of augmented communication have been revealed, future studies should look deeper into methods of making communication efficient and into finding the most suitable forms of communication for different situations.

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Appendix A. Demographic information for explicit communication

1. **Please enter your demographic information**
   Name
   Email
   City
   Country
   Age
   Profession
   Gender

2. **Please enter the demographic information of your partner**
   Name
   Email
   City
   Country
   Age
   Profession
   Gender

3. **In August or September, will you be part of a long distance or semi long distance relationship e.g. will one of you be travelling, working in a different city, living in a different city or country?**
   Yes**/** No
   If yes, please explain

4. **How do you communicate with your partner at the moment?**
   Phone
   VOIP e.g. Skype
   Video Calls
   Text Messages
   Emails
   Instant Messenger
   Social Network Sites e.g. Facebook

5. **Where are you usually located when you call, message or email your partner?**
   Home
   Work
   Travelling
   Other (please specify)

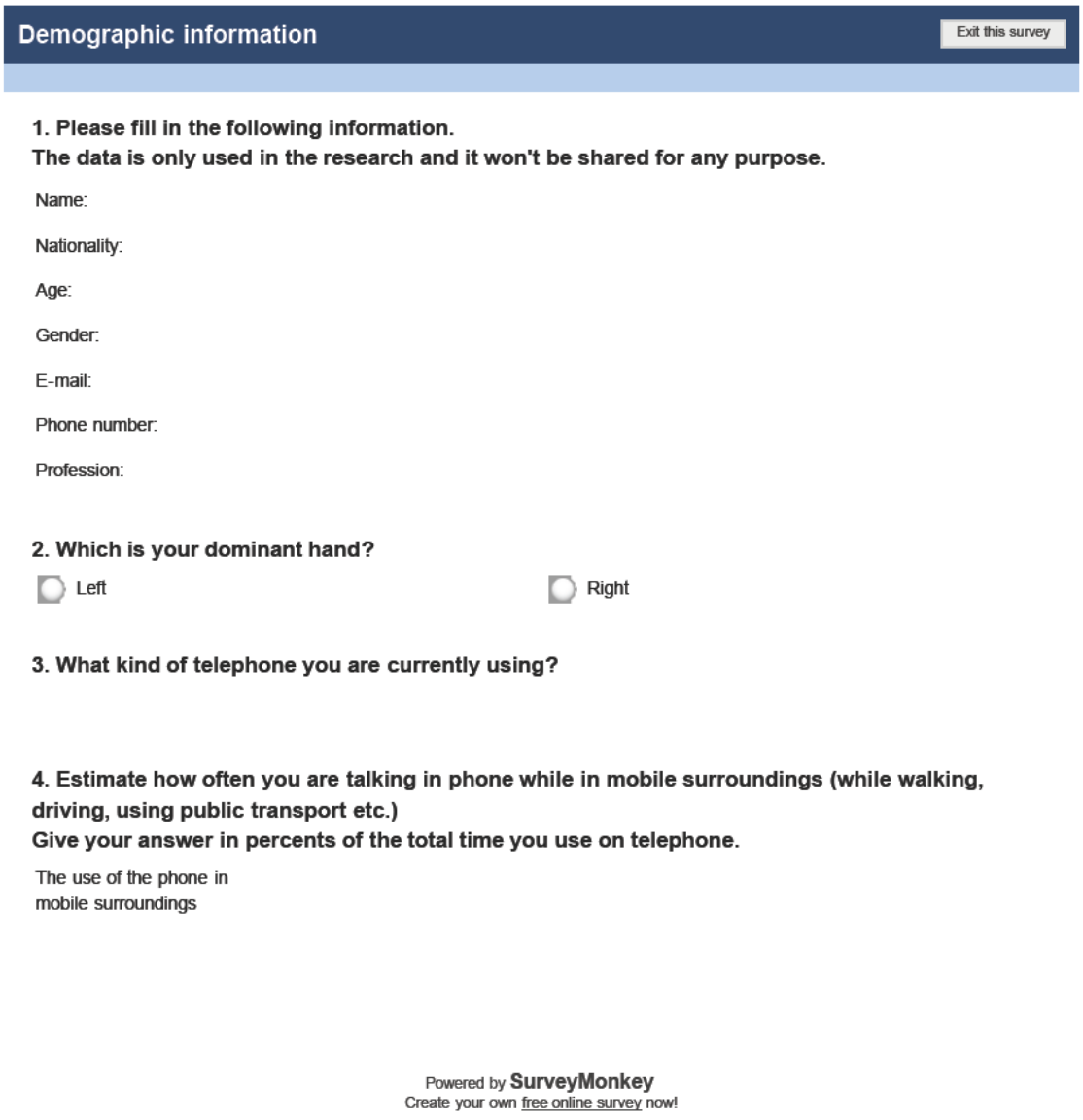
6. **What type of mobile device do you use at the moment?**

7. **Would you and your partner be willing to use the prototype phone for a whole month?**
   Yes/ No
   It depends (please specify)

8. **Would you be willing to fill in a very short questionnaire each time you speak on the phone with each other?**
   Yes/ No It depends (please specify)

9. **We are trying to augment traditional phone calls with the sense of touch. Touch can be a very emotional and subtle form of communication. It may help to transmit the things you don't want to say out loud or can't communicate in words. Do you ever wish you could squeeze your partner's hand or give them a nudge or a hug over the phone? Please give details**

Appendix B. Demographic information for implicit communication



Demographic information

Exit this survey

1. Please fill in the following information.
The data is only used in the research and it won't be shared for any purpose.

Name:

Nationality:

Age:

Gender:

E-mail:

Phone number:

Profession:

2. Which is your dominant hand?

Left

Right

3. What kind of telephone you are currently using?

4. Estimate how often you are talking in phone while in mobile surroundings (while walking, driving, using public transport etc.)
Give your answer in percents of the total time you use on telephone.

The use of the phone in
mobile surroundings

Powered by **SurveyMonkey**
Create your own free online survey now!

Appendix C. Personality test BFI-10

Personality test

Instruction: How well do the following statements describe your personality?

I see myself as someone who …

1. is reserved
   [-2] Disagree strongly [-1] Disagree a little [0] Neither agree or disagree [1] Agree a little [2] Agree strongly
2. is generally trusting
   [-2] Disagree strongly [-1] Disagree a little [0] Neither agree or disagree [1] Agree a little [2] Agree strongly
3. tends to be lazy
   [-2] Disagree strongly [-1] Disagree a little [0] Neither agree or disagree [1] Agree a little [2] Agree strongly
4. is relaxed, handles stress well
   [-2] Disagree strongly [-1] Disagree a little [0] Neither agree or disagree [1] Agree a little [2] Agree strongly
5. has few artistic interests
   [-2] Disagree strongly [-1] Disagree a little [0] Neither agree or disagree [1] Agree a little [2] Agree strongly
6. is outgoing, sociable
   [-2] Disagree strongly [-1] Disagree a little [0] Neither agree or disagree [1] Agree a little [2] Agree strongly
7. tends to find fault with others
   [-2] Disagree strongly [-1] Disagree a little [0] Neither agree or disagree [1] Agree a little [2] Agree strongly
8. does a thorough job
   [-2] Disagree strongly [-1] Disagree a little [0] Neither agree or disagree [1] Agree a little [2] Agree strongly
9. gets nervous easily
   [-2] Disagree strongly [-1] Disagree a little [0] Neither agree or disagree [1] Agree a little [2] Agree strongly
10. has an active imagination
    [-2] Disagree strongly [-1] Disagree a little [0] Neither agree or disagree [1] Agree a little [2] Agree strongly

Scoring the BFI-10 scales:

Extraversion: 1R, 6; Agreeableness: 2, 7R; Conscientiousness: 3R, 8;
Neuroticism: 4R, 9; Openness: 5R; 10 (R = item is reversed-scored)

So for example Extroversion is -Q1+Q6.

Appendix D. Briggs-Myers Type Indicator

You are almost never late for your appointments
YES NO

You like to be engaged in an active and fast-paced job
YES NO

You enjoy having a wide circle of acquaintances
YES NO

You feel involved when watching TV soaps
YES NO

You are usually the first to react to a sudden event: the telephone ringing or unexpected que
YES NO

You are more interested in a general idea than in the details of its realization
YES NO

You tend to be unbiased even if this might endanger your good relations with people
YES NO

Strict observance of the established rules is likely to prevent a good outcome
YES NO

It's difficult to get you excited
YES NO

It is in your nature to assume responsibility
YES NO

You often think about humankind and its destiny
YES NO

You believe the best decision is one that can be easily changed
YES NO

Objective criticism is always useful in any activity
YES NO

You prefer to act immediately rather than speculate about various options
YES NO

You trust reason rather than feelings
YES NO

You are inclined to rely more on improvisation than on careful planning
YES NO

You spend your leisure time actively socializing with a group of people, attending parties, shopping, etc.
YES NO

You usually plan your actions in advance
YES NO

Your actions are frequently influenced by emotions
YES NO

You are a person somewhat reserved and distant in communication
YES NO

You know how to put every minute of your time to good purpose
YES NO

You readily help people while asking nothing in return

YES NO

You often contemplate about the complexity of life
YES NO

After prolonged socializing you feel you need to get away and be alone
YES NO

You often do jobs in a hurry
YES NO

You easily see the general principle behind specific occurrences
YES NO

You frequently and easily express your feelings and emotions
YES NO

You find it difficult to speak loudly
YES NO

You get bored if you have to read theoretical books
YES NO

You tend to sympathize with other people
YES NO

You value justice higher than mercy
YES NO

You rapidly get involved in social life at a new workplace
YES NO

The more people with whom you speak, the better you feel
YES NO

You tend to rely on your experience rather than on theoretical alternatives
YES NO

You like to keep a check on how things are progressing
YES NO

You easily empathize with the concerns of other people
YES NO

Often you prefer to read a book than go to a party
YES NO

You enjoy being at the center of events in which other people are directly involved
YES NO
!

You are more inclined to experiment than to follow familiar approaches
YES NO

You avoid being bound by obligations
YES NO

You are strongly touched by the stories about people's troubles
YES NO

Deadlines seem to you to be of relative, rather than absolute, importance
YES NO

You prefer to isolate yourself from outside noises
YES NO

It's essential for you to try things with your own hands
YES NO

You think that almost everything can be analyzed
YES NO

You do your best to complete a task on time
YES NO

You take pleasure in putting things in order
YES NO

You feel at ease in a crowd
YES NO

You have good control over your desires and temptations
YES NO

You easily understand new theoretical principles
YES NO

The process of searching for a solution is more important to you than the solution itself
YES NO

You usually place yourself nearer to the side than in the center of the room
YES NO

When solving a problem you would rather follow a familiar approach than seek a new one
YES NO

You try to stand firmly by your principles
YES NO

A thirst for adventure is close to your heart
YES NO

You prefer meeting in small groups to interaction with lots of people
YES NO

When considering a situation you pay more attention to the current situation and less to a possible sequence of events
YES NO

You consider the scientific approach to be the best
YES NO

You find it difficult to talk about your feelings
YES NO

You often spend time thinking of how things could be improved
YES NO

Your decisions are based more on the feelings of a moment than on the careful planning
YES NO

You prefer to spend your leisure time alone or relaxing in a tranquil family atmosphere
YES NO

You feel more comfortable sticking to conventional ways
YES NO

You are easily affected by strong emotions
YES NO

You are always looking for opportunities
YES NO

Your desk, workbench etc. is usually neat and orderly
YES NO

As a rule, current preoccupations worry you more than your future plans
YES NO

You get pleasure from solitary walks
YES NO

It is easy for you to communicate in social situations
YES NO

You are consistent in your habits
YES NO

You willingly involve yourself in matters which engage your sympathies
YES NO

You easily perceive various ways in which events could develop
YES NO

Appendix E. Quality of the call for both studies

Quality of the call Exit this survey

Call quality

1. Estimate the quality of the call.
0 not att all
8 extremely

	0	1	2	3	4	5	6	7	8
Well- coordinated	○	○	○	○	○	○	○	○	○
Boring	○	○	○	○	○	○	○	○	○
Cooperative	○	○	○	○	○	○	○	○	○
Harmonious	○	○	○	○	○	○	○	○	○
Satisfying	○	○	○	○	○	○	○	○	○
Comfortably paced	○	○	○	○	○	○	○	○	○
Cold	○	○	○	○	○	○	○	○	○
Awkward	○	○	○	○	○	○	○	○	○
Engrossing	○	○	○	○	○	○	○	○	○
Focused	○	○	○	○	○	○	○	○	○
Involving	○	○	○	○	○	○	○	○	○
Intense	○	○	○	○	○	○	○	○	○
Friendly	○	○	○	○	○	○	○	○	○
Active	○	○	○	○	○	○	○	○	○
Positive	○	○	○	○	○	○	○	○	○
Dull	○	○	○	○	○	○	○	○	○
Worthwhile	○	○	○	○	○	○	○	○	○
Slow	○	○	○	○	○	○	○	○	○

Appendix F. After research questionnaire for implicit communication

After research survey

Exit this survey

1. Did you use your dominant hand to hold the phone?

- Yes
- No

2. Did you change your hand or your hands position consciously during the call?

- Yes
- No

3. If yes, describe why

4. Would you be interested to receive for example pressure data or position data from the other persons phone during the phone call?

- Yes
- No

5. If yes, what kind of information would you be interested in?

6. Any other comments?

Appendix G. Questions in interview for explicit communication

1. How often did you use the pressure/vibration function
2. What kind of topics were you talking about when you sent the pressure/vibration message? (describe the general topic of as many conversations as you can remember)
3. Why did you choose to send pressure/vibration messages? (list as many different reasons as possible)
4. How often did you receive a pressure/vibration message from your partner
5. What kind of topics were you talking about when you received the pressure/vibration message? (describe the general topic of as many conversations as you can remember)
6. What do you think your partner was trying to communicate with the pressure/vibration message?
7. Where were you located most of the time when using the device?
8. Would you like to continue using this feature if it was available in commercial devices?
9. What changes would you make to the device?
10. What did you like best about the device? What did you like least about the device?
11. What is your dominant hand?
12. Did you find the squeezing or vibrations distracting?
13. Did you ever use hands-free? What were your first impressions of the phone?
14. Did you ever accidentally squeeze the phone? Please describe when it happened and your partner's response
15. Did you have any expectations before you began the experiment? Did the device meet those expectations?
16. Did you assign different meanings to the four different levels of pressure/vibration? If so, please describe
17. Was the device comfortable to use?
18. If you didn't use the vibration function regularly, why not? Was it too difficult, too uncomfortable, not useful?
19. Did the vibration signal disturb the conversation or was it easy to continue the conversation normally?
20. Anything else?

Note: the order of the questions changed based on how the discussion was going.