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Understanding Roles and User Experience of Mobile Technology in Co-located Interaction

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Abstract

Over the last few decades, mobile phones have evolved into ubiquitous devices that support remote communication and various kinds of personal activities. Due to their personal nature, device users are engaged in interactions on mobile devices and pay less attention to other people around them. Furthermore, as the user interface is optimized for a single person use, it reduces sharing and interaction capabilities with co-located people, which negatively influences the opportunities for shared experiences and social activities. This thesis attempts to understand how mobile technology can be designed for co-located interaction.

Previous literature on the topic indicates that mobile technology is designed and employed in co-located interaction to fulfill one of these objectives - *inviting interaction*, *facilitating interaction*, *encouraging interaction* or *enforcing interaction.* While mobile technology *facilitating interaction* is investigated the most, this research further explores the remaining three objectives.

This thesis belongs to the research field of Human-Computer Interaction (HCI) and Computer-Supported Cooperative Work (CSCW). This research follows research through design approach, producing the contribution of knowledge through design interventions. This compound thesis includes six studies, introducing seven concepts for mobile application, a novel design for a mobile device, and two functional prototypes. Four studies explore mobile technology *'inviting interaction'*; one study explores the technology aiming to '*encourage interaction*' and the other study explores the mobile technology '*enforcing interaction'*. The intended contexts of use are for leisure and non-work-related activities, with an emphasis on enhancing the co-located social interaction in the activities.

The empirical findings of this thesis include both subjective user experiences and objective observations of users' interactions engendered by mobile technology as well as reflections on the findings in light of existing literature. Based on these findings, this thesis provides insights about 1) The user experience in respect to mobile technology in different co-located interactions; and 2) The roles that mobile technology can play in co-located social interactions, and the design implications describing properties that influence interaction and collaboration between co-located users. These insights provide understandings about mobile technology for researchers and designers dealing with the co-located interaction domain. In addition, this thesis introduces a model of designing mobile technology for co-located interaction. The model intends to help researchers and designers in their early research and design process of mobile technology for co-located interaction. The model is built upon the relation between design objectives, design perspectives, dealing with limitations of mobile technology and the roles of technology in co-located interaction.

Preface

This research is a journey started in February 2013 as a part of COSMO project funded by the Academy of Finland. I am happy to have had fantastic supports from people around me. I cannot thank them enough.

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Tampere 16 November 2016 Pradthana Jarusriboonchai

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The thesis consists of a summary and the following original publications. The candidate's contribution to the publications and studies behind them are described in the following. The publications are reproduced by the permission of the publishers:

Publication I: Jarusriboonchai, P., Olsson, T., Ojala, J. and Väänänen, K. Opportunities and Challenges of Mobile Applications as "Tickets-to-Talk": A Scenario-Based User Study. In Proceedings of the 13th International Conference on Mobile and Ubiquitous Multimedia (MUM'14). ACM Press (2014), 89-97.

Jarusriboonchai planned the study in collaboration with Olsson and was responsible for conducting the study. The analysis was carried out together with her colleagues. She was the principal author and was in charge of producing the publication.

Publication II: Jarusriboonchai, P., Olsson, T. and Väänänen, K. User Experience of Proactive Audio-Based Social Devices: a Wizard-of-Oz Study. In Proceedings of the 13th International Conference on Mobile and Ubiquitous Multimedia (MUM'14). ACM Press (2014), 98-406.

Jarusriboonchai planned the study in collaboration with Olsson. She was responsible for conducting the study. The analysis was carried out together with her colleagues. She was the principal author and was in charge of producing the publication.

Publication III: Jarusriboonchai, P., Olsson, T. and Väänänen-Vainio-Mattila, K. Social Displays on Mobile Devices: Increasing Collocated People's Awareness of the User's Activities. In Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI'15). ACM Press (2015), 254-263.

Jarusriboonchai planned the study in collaboration with Olsson. She was responsible for conducting the study and analyzing the finding. She was the principal author and was in charge of producing the publication.

Publication IV: Jarusriboonchai, P., Malapaschas, A., Olsson, T. and Väänänen, K. Increasing Collocated People's Awareness of the Mobile User's Activities: a Field Trial of Social Displays. In Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing (CSCW'16). ACM Press (2016), 1691-1702.

Jarusriboonchai planned the study in collaboration with Olsson. The study was conducted in collaboration with Malapaschas. The analysis was carried out together with her colleagues. She was the principal author and was in charge of producing the publication.

Publication V: Jarusriboonchai, P., Malapaschas, A., and Olsson, T. Design and Evaluation of a Multi-Player Mobile Game for Icebreaking Activity. In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI'16). ACM Press (2016), 4366-4377.

Jarusriboonchai planned the study in collaboration with Malapaschas and Olsson. Most of the analysis was carried out by Jarusriboonchai. She was the principle author and was in charge of producing the publication.

Publication VI: Jarusriboonchai, P., Olsson, T., Lundgren, S., and Väänänen, K. Let's Take Photos Together: Exploring Asymmetrical Interaction Abilities on Mobile Camera Phones. In Proceedings of the 18th International Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI'16). ACM Press (2016)

Jarusriboonchai led the planning of the study, conducted the study, and performed the analysis of the findings. She was the principal author and was in charge of producing the publication.

1. Introduction

We are living in an age where computers are no longer only on a desktop, but ubiquitous and mobile enough to accompany users everywhere. Mobile phones have developed far beyond their original features of calling, SMS, and voice mail. Their great computing power, Internet connectivity and applications on "app stores" support various kinds of activities. They also enable constant connectivity between people in distributed locations and make accessing digital content and activities more pervasive. This has transferred people to a new state in life - a life that is always on (Turkle, 2011). This results in many benefits - entertainment, time passing and staying current and up to date (Oulasvirta et al., 2011). They also provide users with options to escape from the flow of physical life to something more favorable online. Consequently, many users have their mobile devices as an uninvited companion, distracting them from their physical and offline activities (Ames, 2013; Oulasvirta et al., 2011).

Turkle (2011) refers to *life in a media bubble* as a state of mind, where mobile device users become absent-minded from their physical surroundings, and they engage themselves in their activities on mobile devices. These engagements only make sense to the device users, but not to others in the users' actual surroundings. Furthermore, the presence of mobile devices in dyad social settings negatively influences the quality of interaction (Przybylski and Weinstein, 2012). While these behaviors may not have a significant effect in a group activity, they are often considered rude and disrespectful (Kleinman, 2007). Similarly, Rogers (2014) stated in one of her presentations that with the current trend of technology, people are living in their own *digital bubble* – head-down and glued to a mobile device. This inspires designers and developers to explore technology that encourages head-up interaction, interacting with other co-located individuals and their physical surroundings. Correspondingly, there are public and society-led campaigns that raise awareness about the overuse of mobile technology (e.g., #notonappstor[1] or stop phubbing[2]).

In fact, mobile devices are also used as a part of social face-to-face interaction. Examples being as a conversation starter and enhancer, a group entertainer, or a common play space (Oulasvirta et al., 2011; Church et al., 2012; Ames, 2013; Brown et al., 2014). Certain previous studies have shown that users have established their own ways to adapt to mobile devices as a part of their shared activities, for example, by speaking the content aloud, showing the screen to others or passing the device around (Weilenmann and Larrson,

[1]http://notonappstore.com/ (last accessed 16 February 2016)
[2]http://stopphubbing.com/ (last accessed 16 February 2016)

2001; Church et al., 2012). Furthermore, the portable form factor of mobile devices allows users to carry technology with them in a variety of contexts and situations and does not limit them to use it only at their desk. For example, mobile devices allow technology to enhance the learning experience in the field (Cole and Stanton, 2003), instead of being stuck with desktop computers or other stationary technology in a classroom.

Mobile devices may distract users from conversations and interactions with others in their physical surroundings. However, they can provide good conversation topics and great support for a joint activity. Mobile technology has recently gained more attention from Human-Computer Interaction (HCI), Computer-Supported Cooperative Work (CSCW) and Ubiquitous Computing (UbiComp) communities, for its potential to support local interaction and collaboration (Memarovic et al., 2012; Jarusriboonchai et al., 2014; Lucero et al., 2015; Fischer et al., 2016). A large body of research has explored mobile technology in co-located interaction and collaboration from different perspectives. Some samples are technical systems (Hinckley 2003), interaction techniques (Lucero et al., 2011), facilitating and increasing task efficiency (Lim et al., 2014), enhancing an activity experience (Clawson et al., 2008) or monitoring interaction and collaboration (Feese et al., 2013). While these existing works contribute to a large corpus of knowledge for HCI and CSCW, the communities still lack a general understanding of mobile technology in co-located interaction.

1.1 Scope and Focus of the Thesis

This thesis belongs to the fields of HCI and CSCW. This research looks into the user experience and the emerging social interaction patterns between co-located users while using mobile technology. Generally, mobile technology is applicable in a variety of activity domains and for different purposes. The main context of this thesis is when users are *co-located*. That is, a circumstance when people are present together sharing a physical space (Goffman 1963). This research employs mobile technology in situations that users only share the space, but have not yet interacted with each other as well as situations where the users are already engaged in an interaction with each other. This thesis focuses on the use of mobile technology to *enhance* and *support co-located social interaction* and *collaboration* in leisure and non-work-related activities. The goal is to identify the roles that mobile technology has in co-located social situations. The outcomes of the research contribute to the understandings in designing mobile technology for the domain.

Nowadays, mobile technology is available in a wide variety of forms - smartphones, smartwatches, tablets or custom wearable devices. The current thesis focuses on the mobile devices in the form of mobile smartphones. They are entitled as mobile devices, instead of mobile phones or smartphones, as this research does not utilize their features as phones (i.e., as a remote audio-based communication device), but as computing devices with various features like a camera, a game console or an entertainment terminal. Furthermore, the context of the study is not limited to the users being mobile, but also employing mobile devices during stationary activities.

1.2 Research Questions and Contributions

The overall research goal of this study is to gain better understanding of mobile technology in co-located interactions. To address this research goal, it is important to understand how different designs of mobile devices and applications influence a co-located interaction. Hence, the main research questions of this thesis are:

RQ 1: What are the outcomes of introducing mobile technology into a co-located interaction?

a. What kinds of interaction practices emerge as outcomes of mobile technology enhancing co-located interaction?
b. What are the user experiences of mobile technology enhancing co-located interaction?

RQ 2: What are roles and considerations for designing mobile technology enhancing co-located interaction?

The first question examines the objective observation of users' interactions and the subjective user experience about the designs and concepts of mobile technology in co-located interaction. The question addresses the reflections from users' perspectives. This also includes the interaction practices between the users engendered by the technology. The second research question seeks to identify the roles of mobile technology and considerations for designing the technology for enhancing co-located interaction. The outcome reflects on the concepts and designs from both designers' and researchers' perspectives.

The contribution of this thesis is three-fold. The first is for understanding the role of mobile technology in co-located interactions and the design implications. This can point out the design properties of mobile technology that can affect the interaction and collaboration between co-located users. The second contribution is for application concepts, system designs, and findings from the user studies. This is a practical impact inspiring future design for specific contexts and activity domains. Furthermore, the design process and overall findings of the thesis also contributes to the model for designing mobile technology for co-located interactions. The model can provide guidance in design thinking process for researchers and designers in how to design mobile technology for this particular domain.

1.3 Research Methods and Approach

Interaction between users, social implications and experience of technology cannot be envisioned well enough without having functional prototypes. Winograd (1986, p.219) noted, "*every time system is built into a work setting, the work is redesigned—either consciously or unconsciously. We cannot choose to have no impact, just as we cannot choose to be outside of a perspective. We can make conscious choices as to which ones we follow and what consequence we anticipate*". Thus, this thesis follows research through design approach (Zimmerman et al., 2007) to generate better understandings of mobile technology in co-located interactions. In addition to extensive literature review, designs and application concepts are introduced as design apparatus, based on the various theoretical foundations and frameworks, in order to explore the design space and study users' reactions, practices and experiences. Throughout the research process, several conceptual designs and prototypes (seven conceptual designs of mobile application, one physical mock up, and two functional prototypes) are built. These designs are based on the integration of multidisciplinary theories and knowledge (e.g., sociology, technology, and interaction design patterns) and are evaluated with the users. Findings from the user studies reflect with the related work to develop understandings that will benefit the future design of the technology.

This thesis includes six user studies employing a variety of design methods. Scenarios (Carroll, 2000) and storyboards (Truong et al., 2006) were medium used to communicate early concepts of mobile technology to the participants. For a semi-functional prototype, the situation that the prototype was intended to use was simulated, and employed Wizard of Oz technique (Dow et al., 2005) to allow participants to experience the system in order to gather an early feedback. A field study and user trials were also conducted with fully functional prototypes. User trials often involve an experimental design during the planning, but the actual studies are usually unstructured and closer to natural settings (Brown et al., 2011). They allow researchers to observe unanticipated appropriations and interactions with the system that would not otherwise emerge in a strictly controlled laboratory study. Field study allows users to possess the technology on a daily basis and there is a possibility that certain aspects that users themselves have not thought about before emerge. These studies are usually accompanied with a focus group (Morgan, 1996) and individual or pair semi-structured interview, in order to discuss their thoughts and feedback. Questionnaire was employed in the field study to compare the experience and report incidents before, during, and after the trial. The choice of methodologies depends on the novelty of the concepts, available of technology at the time, and possibilities to conduct studies. Chapter 5 further explains these methodology choices and research approach for each case study conducted in the thesis.

All studies produced qualitative data (video and/or audio recordings) with quantitative data in one study, in order to compare the experience before and after using the prototype. Qualitative data was analyzed with qualitative content analysis (Elo & Kyngäs 2008), particularly with an affinity diagram (Beyer and Holtzblatt, 1998) that produced a data-driven and bottom-up hierarchy of themes.

1.4 Structure of the Thesis

This thesis includes seven chapters. **Chapter 1** is the introduction to the research. **Chapter 2** provides a background of the research fields. **Chapter 3** provides in depth review of the related work. The chapter also introduces *design objectives* of mobile technology, which helped in guiding the design decisions for user studies conducted in this thesis. **Chapter 4** summarizes the research process and methods utilized in this research. **Chapter 5** presents summary of user studies conducted in the thesis. The summary includes positioning and design approach, methodology, and findings from each study. **Chapter 6** presents the main results of this research, i.e. the model for designing mobile technology for co-located interaction. The model is built from insights and knowledge gained throughout this research, including design perspectives for managing limitations in mobile technology, roles of the technology, and design implications for the roles. The model presents the overall relation between design objectives, design perspectives, and the roles. **Chapter 7** revisits the research questions and summarizes the contributions of this thesis. It also includes a methodological discussion and suggestions for future research.

2. Background

This chapter provides background of the research fields for this thesis. The thesis belongs to the field of Computer-Supported Cooperative Work (CSCW), which is the sub-field of Human-Computer Interaction (HCI). This research focuses particularly on social interactions and technology. Mobile and ubiquitous computing is another field that this research relates to, and considers the concepts like awareness, omnipresent mobile technology, and the technology moving away from the main attentions of users. The following sections further describe the background and research fields in detail.

2.1 Social Interaction and Technology

Social interaction is an aspect of life that human beings encounter every day. Social interaction leads to the feeling of belonging (Kahneman et al., 1999; Sheldon, 2001), which is one of the five fundamental psychological needs (Maslow et al. 1970). Social interactions happen already when people are present in the same physical space. Goffman (1963) refers to this as an *unfocused interaction*. This is when people communicate through their presence, i.e., bodily gestures and personal action in the space: "*no one participant can be officially 'given the floor'; there is no official center of attention.*" (Goffman 1963, p.34). However, these interactions are close to none as in some cases when people may act as if others are not even there. Bonding between people does not occur from unfocused interaction, but from focused interaction. *Focused interaction* is a situation where people join each other and are engaged in a mutual activity that excludes the co-presence of others. This is also known as an *encounter* or a *face engagement* (Goffman 1963). An encounter may include exchanging verbal statements, e.g., in small talk, a meeting, a use of service, as well as being without verbal statements, e.g., between adults and babies. While acquaintances need a reason not to enter a face engagement, strangers need reasons to trigger a shift from unfocused interaction to focused interaction. The reasons could be the social position of a person (e.g., the police interact with an elderly person to help him/her), special relationships between people (e.g., a man with a sports jersey greets another stranger with the same sports jersey at a bus stop), or special occasions (e.g., a carnival).

Social interaction directly affects people's well-being, both physically and mentally (Sigman, 2009; Baumeister and Leary, 1995). Moving beyond an individual emotional and health benefits, social interaction between people also affects the quality of community. For example, interaction and familiarity between neighbors can promote security and decrease crime rate in a community (Bellair 1997; Putnam 1995). Social interaction not only provides companions and social support, but also enables information and knowledge sharing (Lee et al., 2001). It is also a key element of teamwork and collaborative activities, stating that if there is no social interaction, then there is no real collaboration (Kreijns et al., 2003). Furthermore, social interaction can enhance performance and experience of an activity. For example, in learning domain, social interaction can trigger cognitive progress and development, by encouraging leaners to reconstruct their ideas through discussions. This has been identified to promote learning of new skills and knowledge, as a group as well as individuals (Doise and Graham, 1978; Johnson and Johnson, 1994). Similarly, social aspects in multiplayer games is found to provide additional layer of experience to players (Costikyan, 2005).

Emerging technology enables and facilitates social interaction, which yields many operational and experiential benefits. For example, a double screen computer at a service counter enhances trust and effectiveness in an interaction between customer and service provider (Inbar and Tractinsky, 2010); a tabletop system allows equal participation between group members and smooth transitions between personal and group work (S. Scott et al., 2003); and a mobile guidebook application that enables eavesdropping enhances a cultural group’s visiting experience (Szymanski et al., 2007). Technology also extends forms of social interaction, not only limiting it to face-to-face, but also through computer-mediated manners. An appropriate amount of computer-mediated interaction, specifically social network services, is found to reduce loneliness, increase opportunities to reach different group of acquaintances, and provide emotional support, which correlates to well-being (Burke et al., 2010). Furthermore, some systems are intentionally designed to enable and facilitate social interactions, in order to enhance specific activity experience. For example, technology that enables social support in an individual exercise like running, is found to increase motivation and enhance the activity experience (Woźniak et al., 2015). Technology and social interactions share a close relationship. In some cases, technology is designed to enhance social interaction, while in others technology enables social interaction in order to enhance activity experience.

Technology has a straightforward role in enabling interaction and collaboration between people in a distributed and remote interaction. However, roles of technology are different in contexts where people are co-located. In interactions between people who are already fluent, involving technology could potentially hinder the interactions (Lanir et al., 2011; Przybylski and Weinstein, 2012), especially the use of mobile technology where it is designed to support a single user (Turkle 2011). This thesis examines the roles of mobile technology that could play out in the contexts where users are co-located and its potential in enhancing social interaction and activity experience.

2.2 Computer-Supported Cooperative Work

Human-Computer Interaction (HCI) is a multidisciplinary field of study, including knowledge and contributions from computer sciences, sociology, psychology, design, human factors, and many others fields (Lazar et al., 2010). Technology stepped out from research laboratory in the early 1980s and moved into people's homes as personal computers. Users of these computers are no longer experts, but ordinary people without special training who use computers to help with their tasks. This is when interaction between user and computer becomes important, and an early HCI research usually focuses on the usability and efficiency in completing tasks. As computers become ubiquitous, interactions with computer is not about task completion for a single person, but also involves interactions with other users, with and through computers. Furthermore, the purpose of computers is not only for work efficiency and usability, but also connections, communications, collaborations, leisure activities, experiences, entertainments, and games (ibid). A sub-community called Computer Supported Cooperative Work has emerged, which focuses on the collaborative behavior studies and technology.

The term Computer Supported Cooperative Work (CSCW) was first introduced as a workshop organized by Paul Cashman and Irene Greif in 1984, before it developed into a full-fledged conference two years later (Grudin, 1991a). CSCW is not an entirely new research field, but built upon multidisciplinary fields of study, such as distributed computing, human-factors engineering, software engineering, sociology, cognitive sciences, ethnomethodology, and many more. Proposed by Bannon and Schmidt (1989), CSCW "*should be conceived as an endeavor to understand the nature and characteristic of cooperative work with the object of designing adequate computer-based technologies*". The main focus of CSCW is to support multiusers working together with computer systems (Grudin, 1994).

Research within this field usually involves two major approaches - the group working process and the use of technology to support group works (Wilson, 1991). CSCW, as a research field is still developing and evolving. In the early days, CSCW research heavily focused on efficiency and work related tasks, such as group decision supports, electronic meetings, co-authoring documents, etc. It also included research and studies that do not directly involve computer support, but pure behavior pattern studies, e.g., CSCW'88 proceeding (Greif, 1988). As the community evolved, interests and sub-domains beyond the office tasks emerged, such as Computer Supported Collaborative Learning (CSCL) (Koschmann, 1996; Stahl et al., 2006) and Computer Supported Cooperative Play (CSCP) (Ishii et al., 1999).

CSCW was also critiqued and discussed around the terminology of CSCW, as it seemed to create fuzzy boundary within the research field – "*covers anything to do with computer support for activities in which more than one person is involved*" (Bannon and Schmidt, 1989, p.2). However, some researchers consider this a good opportunity to foster multidisciplinary perspective, generate many ideas, and produce useful applications (Bannon et al., 1988). Meanwhile, there emerged a field called Groupware. Groupware is defined as "*computer-based systems that support groups of people engaged in a common task (or goal) and that provide an interface to a shared environment*" (Ellis et al., 1991, p.40). Groupware literally overlaps with CSCW, but covers a narrower view of the field than CSCW. Grudin (1991b) consider Groupware as an application constituent of CSCW. For further clarification, Groupware emphasizes on the technical design and implementation of systems to support group work, while CSCW is the study of the way people work together and effects of computer and technology in group behaviors (Greenberg, 1991; Grudin, 1991b). Nevertheless, the term CSCW is more preferable as a research community, as it is more comprehensive (Greenberg, 1991).

Groupware as a domain includes various application levels, including message systems, multiuser editors, group decision support systems, electronics meetings, computer conferencing, intelligent agents, and coordinate systems. While there are overlaps within these application categories, groupware systems can be simply categorized to support four activity domains in the notion of time and space (same time/different times and same place/different places), Table 1 (Ellis et al., 1991). While face-to-face interaction is included as an activity domain supported with Groupware, early attention in the field is directed to support activities with distributed time and/or space (ibid).

Table 1: Activity domains of groupware in time-space matrix (Ellis et al., 1991). The focus of this thesis is on face-to-face interaction.

	Same Time	*Different Times*
Same Place	Face-to-face interaction	Asynchronous interaction
Different Places	Synchronous distributed interaction	Asynchronous distributed interaction

This thesis falls into HCI and CSCW research fields. The research explores user interaction with mobile technology, involving in interaction and activity between users from both Groupware and traditional CSCW perspectives. This thesis includes hands-on system design intended for group activities, as well as investigates the effects of the designs on group behavior within same time and same place, as the main context of this thesis.

Social computing is another area of research and refers to "any type of computing in which software serves as an intermediary of a focus for social relation" (Schuler, 1994, p.29). Research in this field is a combination of social interface, CSCW, communities, and interpersonal psychology (Dryer et al., 1999). Studies conducted in the field usually apply social and behavior science in design of systems, studying social responses and effects of technology, and trying to understand why these interactions and behaviors take place (Dourish, 2004). While the concept of social computing includes broad areas of technology and social study, the area often refers to studies of social activities on distributed services, such as social networks, massive multiuser online games, crowdsourcing, blogs, Wiki pages, image and video sharing, etc. (Ali-Hassan and Nevo, 2009). Differently, this thesis explores the field of social computing, and focuses on the consequences of certain designs of technology in co-located social interaction.

2.3 Mobile and Ubiquitous Computing

Ubiquitous computing (Ubicomp), also described as pervasive computing, is a concept of technology that disappears in the background; assisting everyday life, providing information and services whenever the users desire, with natural, implicit, and non-intrusive way of interaction (Weiser, 1991; Abowd and Mynatt, 2000). To realize the concept of Ubicomp, researchers need to address these three goals: 1) Everyday practices of people must be understood and supported, 2) The world must be augmented through the provisioning of heterogeneous devices, offering different forms of interactive experiences, and 3) the networked devices must be orchestrated to provide a holistic user experience (Abowd et al., 2002).

Thus, research in Ubicomp usually evolves around the themes of natural interfaces, context-aware computing, including capturing context for information retrieval and adapting devices behavior to match with the current usage, automated capture and access live experience, so that users are fully engaged to the activity without having to worry about collecting specific details (Abowd and Mynatt 2000). Various technologies are employed to implement Ubicomp concept. For instance, mobile computing, interactive shared display, tangible user interfaces, augment reality, network and communication, etc. This shift of technology from desktop computers to mobile and ubiquitous technology has resulted in the technology being the background and not the main object of interest, and supporting collaboration and interaction between users (Dryer et al., 1999; Abowd et al., 2002). There are overlaps between Ubicomp and CSCW, with Ubicomp emphasizing more on integrating multiple devices in one setting (Abowd et al., 2002). This research is not about Ubicomp in terms of adaptive behavior or context aware systems; rather, it considers the relevant concept of Ubicomp, that is, employing and designing multiple mobile devices with a context that the devices are not the main focus during the interactions.

3. Related Work

Technology enhancing co-located interaction has already been explored in the field of CSCW, and different advanced technology has been introduced. Single Display Groupware systems are the early technology that enabled co-located collaborations by providing co-located users with multiple input devices, e.g., mice, to interact with a single computer (Stewart et al., 1999). Wall display, tabletop system, and tabletop and tangible systems are later trends of Single Display Groupware that are broadly employed in supporting co-located interaction (Ju et al., 2008; Scott et al., 2004; Stanton et al., 2001). Recently, mobile technology has been more advanced in computing power and is competent for various tasks. Researchers and designers have been considering mobile technology to support co-located interactions and collaborations. Mobile technology is exploited both as a standalone technology (Lucero et al., 2011) and as an integration to other systems like a tabletop display (Goh et al., 2014). This chapter further describes previous research on the technology enhancing co-located interaction.

3.1 Mobile Technology in Co-located Interaction

Mobile technology is already permeating and exists in people's daily lives. The small size and personal nature of mobile devices can draw users' attentions away from the ongoing activity and hinder some aspects of group interaction (Turkle, 2011; Ko et al., 2015). In spite of this, people use mobile devices for various social purposes, e.g., searching and sharing information relevant for several co-located users. People have established their own ways to include mobile devices as a part of their shared activities. For example, Weilenmann and Larrson (2001) and Church et al. (2012) explored the use of mobile search in co-located group settings and found that speaking the content aloud, showing screen to others, and passing the device around, are some of the common practices for sharing information with mobile devices in co-located situations. Furthermore, portable characteristics, advanced computing power and connectivity of mobile, releases physical limitation of technology from being stationary, and allows the devices to be carried around and applied to broader activities.

This contradiction between properties of mobile devices and their potential makes mobile devices in co-located interaction an interesting design space. In fact, personal and intimate characteristics of mobile devices is not stopping the researchers and designers to utilize the technology for co-located uses. They are considered as challenges that can be overcome or taken an advantage of in some specific contexts. For example, portable and personal characteristic of mobile devices can offer fluid and dynamic information, face-to-face interaction, but limit sharing actions between users. To overcome this, Marquardt et al. (2012) created an interactive space using visual tracking technology, which employs gesture, orientation of mobile devices, and orientation between users to facilitate natural way of sharing digital content across devices. A broad range of systems and designs have been built and studied in order to explore mobile technology for co-located interaction in diverse activities and domains. For instance, office tasks and meetings (Lim et al., 2014), museums and theme parks (Aoki et al., 2002; Durrant et al., 2011)), learning (Danesh et al., 2001; Cole and Stanton, 2003), photo sharing (Lucero et al., 2011), gaming (Falk et al., 2001), and many more.

Based on the literature review, systems and designs of mobile technology in co-located interaction can be grouped based on their aims to fulfill four design objectives: *inviting*, *facilitating*, *encouraging*, and, *enforcing* interaction (Table 2). These categories are similar to design approaches by Benford et al. (2000) in designing technology for collaboration on shared interfaces. These categories extend Benford et al. framework in forms of technology, from shared interfaces (e.g., tabletop) to mobile technology (both with and without shared interfaces). Furthermore, the literature review shows that mobile technology is used for broader purposes, not only for collaborative purposes, but also to enhance and support interaction and experience of users in a group activity, including providing topics for conversation or a play space to compete with each other. The following sections further describe the four objectives and highlights some examples of related work.

Table 2: Design objectives for designing mobile technology for co-located interaction

Design objectives	**Descriptions**
Inviting interaction	Initiate, trigger, and provoke co-located interaction
Facilitating interaction	Enable and facilitate co-located interaction and collaboration
Encouraging interaction	Incentivize users to interact and collaborate with each other
Enforcing interaction	Requires users to perform synchronized actions to succeed in a task

3.2 Mobile Technology *Inviting* Co-located Interaction

Mobile technology inviting co-located interaction initiates, triggers and provokes face-to-face interaction between people, before and during an encounter. The following section provides examples of systems designed to invite interaction between strangers and acquaintances, across different contexts.

Social matching systems generally aim to bring people together, either physically or digitally (Terveen and McDonald, 2005). *CommonTies* is a match-making system that supports networking in professional events, like conferences (Chen and Abouzied, 2016).

CommonTies triggers face-to-face interaction between strangers using a single glowing LED on wristband as a signal to identify that there is a match between users. The idea is to minimize computer mediation and allow the users to disclose the information about themselves in their face-to-face interaction. Other systems provide mutual information between users to trigger face-to-face interaction. For example, *Scent* is a profile sharing application with an emphasis on exchanging and matching the mutual contacts in the phonebook between users (Jung et al., 2006). *Scent* was identified to be a conversation facilitator between close colleagues, and as a communication tool between strangers. Social matching systems are famously used as dating services. For example, *Tinder*[3] is a dating service based on mutual interest in one another and being in the proximal physical location.

Some other systems attempt to trigger interaction between users, without functioning as a recommendation or matchmaking system. Mobile technology can bring people together, by providing information about others in the vicinity. For example, Hummingbird is an early interpersonal awareness device that notifies users when they are close to each other (Holmquist et al. 1999). The information is found to help bring colleagues together when they need to meet face-to-face. *DigiDress* is a profile sharing mobile application. Users can browse through profiles of other users, only if the other users are in proximity (Persson et al., 2005). The system is found to create curiosity between most users and trigger interactions between a few users. Providing information can also invite users to join a shared activity. For example, *Walky* applies microblogging to a mundane walking activity and tells the other seniors in a community when someone is going out for a walk, so that others can join (Nazzi and Sokoler, 2011).

Meme Tag triggers face-to-face encounters between event attendees, through an exchange of identity and “memes” (small quotes) on their name tag when users come close to each other (Borovoy et al., 1998). *Meme Tag* initiates interaction with those who otherwise might not have interact with each other without the tag, in a conference situation. *Urbanhermers* is a dynamic fashion accessory that provides users a channel to express and communicate something about themselves to others in the surroundings, and possibly develop some interactions with others (Liu and Donath, 2006). *Billboard* is a two-screen laptop that shows user-generated texts on the outer display, with an aim to invite and support interaction between user and the surrounding people (Kleinman et al., 2015).

For technology inviting co-located interaction, systems and designs also go beyond just triggering interaction between people. They also facilitate face-to-face encounters. For example, *BubbleBadge* is a small wearable display in a broach-like frame attach to user’s cloth like a badge, which provides dynamic information about the user (Falk and Björk,

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[3] Tinder: https://www.gotinder.com/, https://en.wikipedia.org/wiki/Tinder_(app)

1999). The badge provides topics for conversation, which smoothen face-to-face interaction between users and those around them. Similarly, *Social Textile*, a wearable system, reveals commonalities between two users after a social greeting through skin contact, such as a handshake or a high five (Kan et al., 2015). *Mugshot* is a coffee mug with a small display attached to it, presenting an image. The mug is intended to facilitate social interaction during an encounter, both between strangers and acquaintances (Kao and Schmandt, 2015).

Alternatively, *Meeting Mediator* is a mobile system that detects and provides real-time feedback of speaking time, average speech segment length, and other social interactions of each participant in a meeting (Kim et al., 2008). The system encourages equal participation in a group meeting and reduces the differences between dominant and non-dominant people.

3.3 Mobile Technology *Facilitating* Co-located Interaction

Mobile technology facilitating interaction enables and facilitates interactions and collaboration between co-located users. Enabling interaction means technology makes possible for co-located users to interact with each other. Interactions between users in some systems are enabled through multiuser interface design and connectivity between devices. For example, *Pirate!* is a multi-player location-based game, in which players have to walk around the physical environment to explore the virtual game environment. The game triggers an option to compete with another player, if it detects any players within close proximity (Falk et al., 2001). While social interaction is not necessary, the authors argue that it naturally occurs during the game. *MultiDraw* is a multi-user drawing application using multiple tablets for a small group of users (Yuill et al., 2013). The game is based on the game of *Picture Consequences*[4]. In each round, a group member draws a specific part of the picture and then passes the tablet to the next person until the picture is completed. *Ambient Wood* is a mobile technology that enhances outdoor experience for pairs of young students. While one device is a probe, the other displays the probing results and presents location specific information to users in a collaborative outdoor learning activity (Cole and Stanton, 2003). Users have their own devices and are provided with responsible tasks, and they occasionally need to come together to share information. The authors argue that employing multiple mobile devices in co-located interaction can better support the activity than continually working on a single device. However, information on a single device being shared should be simple enough to be easily communicated through verbal communication between users (Cole and Stanton, 2003; Reilly et al., 2008).

[4] Picture Consequences: https://en.wikipedia.org/wiki/Picture_consequences

These application concepts of mobile technology can foster co-located interactions and activities fairly well. In addition, researchers and designers also apply variety techniques for designing mobile technology that better facilitate co-located interactions. That is to make interaction and collaboration between co-located people engaged in an activity easier to do.

3.3.1 Shared Display

Common frame of reference, shared attention, awareness of others' actions, and availability of information are important aspects in both remote and co-located interactions (Yuill and Rogers, 2012; Churchill and Snowdon, 1998). Traditional co-located collaboration usually takes place on shared surfaces like whiteboard, paper, or on a tabletop. These interaction spaces provide rich resources for co-located group interaction - common working space, awareness of others' actions, and concurrent interaction (Tang, 1991). Limited support from mobile devices form factors including small sizes and lack of interaction visibility leads to personal and individual nature of use (Mandryk et al., 2001; Szentgyorgyi et al., 2008). Even for desktop and laptop computer, they are suitable for single user, as they have only a single set of keyboard and mouse. This limitation creates interaction seams and design difficulties for maintaining and supporting collaboration.

Single Display Groupware (SDG) is an alternative model that supports collaborative work in co-located situation, around a single computer (Stewart et al., 1999). Users collaborate on a shared computer with multiple, simultaneous and equivalent input channels. This enables interactions that require multiple users, such as collaborative learning, encouraging peer learning and peer teaching to reduce a single user from monopolizing a task and encouraging communication. Sharing a single display also promotes a shared understanding, which leads to easier collaboration. Furthermore, simultaneous interaction from multiple users with the system could lead to positive impacts of user engagement and enjoyment (S. D. Scott et al., 2003). The model is envisioned to be useful in creative, learning, instruction, and sales domains (Stewart et al., 1999).

Mobile devices is employed as tangible tokens, equipped with sensors and/or actuators, which enable a wide variety of interaction possibilities (Klompmaker et al., 2013; Schmidt et al., 2012). They help increasing peripheral awareness, resolve conflicts, and promote turn taking behavior between users (S. Scott et al., 2003; Waldner et al., 2006; Olson et al., 2011). They also provide additional interactive space for users when using SDG. For example, *Poker Surface* is a digital card game on multi-touch tabletop surface with mobile device integration (Shirazi et al. 2009). Mobile devices provide users with private workspace. This enhances the game experience and users prefer using devices for interaction rather than interacting on the table. *MobiSurf* combines mobile devices and a tabletop display to facilitate information sharing and collaborative problem solving (Seifert et al., 2012). Mobile devices are mostly used to complete the individual tasks, while the tabletop helps increase awareness about the actions of other users, change the quality of how users collaborate, facilitate conversations and provide better support for discussions. This combination offers different working states, supports private and parallel works, and collaborative discussions. Different information presented across public and private space promotes interaction and collaboration between users. Such a collaboration cannot take place by employing only interactive tabletop surface. Private and personal characteristics of mobile devices are actually utilized to enhance experience and face-to-face interactions (Hailpern et al. 2007; Goh et al. 2014).

Small display size of mobile device limits viewing angle, sharing, and interaction capability with other co-located people, e.g., not every group member has access to the information, which hinders participation, especially as the group becomes bigger (Lim et al., 2014). One solution is to increase the display size, creating a large shared display. Cowan et al. (2012) propose using projector phone to create a shared display. Projection facilitates spontaneous sharing and trigger conversations within a group of friends (Cowan et al., 2012). *SurfacePhone* proposes another projector configuration of a projector phone, creating a mobile tabletop interactive space to provide both private and public working space (Winkler et al., 2014). This supports flexible group formations - shoulder-to-shoulder and face-to-face positions. Alternative to using projector phone, other designs create a single shared display from a matrix of multiple mobile devices. *Pass-them-around* facilitates a small group photo sharing by stitching array of mobile devices together to create a single tabletop shared display (Lucero et al., 2011).

3.3.2 Shared Workspace and Shared Information Pool

Similar to creating a shared display, other designs create a shared workspace between the mobile devices of co-located users to facilitate co-located interactions. Kun et al. (2007) adopted *What-You-See-Is-What-I-See (WYSIWIS)* paradigm (Stefik et al., 1987) to facilitate co-located photo sharing. All the users have their own devices, synchronized with each other and everybody sees the same view and can equally manipulate the photos. Similarly, *Ubi-jector* facilitates on-the-spot informal meeting by synchronizing the mobile devices of group members to create a shared workspace (Lim et al., 2014). The system is argued to also encourage active participation from group members. *Sotto Voce* is another example of creating a shared space with an audio. Sotto Voce extends the nature of an audio guide, which typically isolates users from each other. It enables eavesdropping of each other’s audio content (Aoki et al., 2002). It is found to enhance cohesive social experience and encourages conversation between users.

Other designs support loosely coupled style of interaction by allowing users to work on a task in parallel and only share the final results. For example, *Pass-them-around* synchronizes all the devices to show the same photo when one of the group members finds an interesting photo and would like to discuss it with others (Lucero et al., 2011). *WaggleBee* is a mobile application that supports mobile web search in a small co-located group. Each user does the search separately and only when a share button, which is on every device, is pressed, then the web content of the user is shared with other group members. (Reis and Church, 2013).

Mobiphos is an automatic mobile photo sharing application that simultaneously shares recently taken photos to a common image pool. The pool is accessible to all the co-located group members (Clawson et al., 2008). Group members have access to the photos in real time. This instant sharing affects the photos that the participants decides to capture and leads to various interactions and collaborations between the co-located group members (e.g., serving as a conversation topic between group members), and novel photography experiences. *Automics* provides instant sharing and collaborative editing between collocated group members (Durrant et al., 2011). The shared pool in *Automics* was appreciated for allowing the users to get photos from the situations they missed and pay attention to other ongoing activities, while others take care of photography.

3.4 Mobile Technology *Encouraging* Co-located Interaction

Systems and designs intended to facilitate co-located interaction and collaboration often aim to increase the level of awareness, freedom of control and interaction with the system, and high availability of information. Nevertheless, varying these factors or constraining some aspects can result in technology that goes beyond merely enabling or facilitating interaction, but also encouraging (Yuill and Rogers, 2012). According to Benford et al. (2000), technology encouraging collaboration provides incentives as motivations for users to collaborate. By collaborating, these incentives make the activity easier, more efficient, or more fun. For example, Sanneblad and Holmquist (2004) designed a collaborative multi-player game named *Pac-Man Must Die*. The game utilizes mobile devices displays of users as a shared space for the game. The game is designed in a way that players have to control their avatars and collect game items that are not only located on their own displays, but also distributed across the displays of other players. Players can take advantage of the game by collaborate with each other, for example, sharing the view to their displays with each other.

Technology encouraging co-located interaction usually employs positive interdependency technique (Johnson and Johnson, 1994) to drive co-located users to interact and collaborate. Mobile technology encouraging interaction is mostly applied to a task that users has individual goals. For example, in *Pac-Man Must Die*, the goal of the activity is an individual goal—i.e., to collect game items and survive as long as possible. Users can still achieve the goal even if they do not collaborate with others, but conditions in the game allow them to take advantage if they do that. This technique is common in designs of interactive tabletop and public display systems to encourage co-located interaction (Fan et al., 2014; Piper et al., 2006).

3.5 Mobile Technology Enforcing Co-located Interaction

In mobile technology encouraging co-located interaction, users can still accomplish their tasks without interacting with other users. Technology enforcing interaction emphasizes in involving other co-located users into an activity. Systems are designed so that one user is unable to complete a task alone, but requires other users to synchronize their actions in order to succeed (Benford et al. 2000). For example, *Spaceteam*[5] is a commercial multiplayer game in which a spaceship is piloted by smartphones and tablets of several co-located players. The game provides each player with different sets of controls on their devices for the shared spaceship and different information about which controls should be manipulated. Players need to communicate in order to perform the correct actions in the game and keep the spaceship in control. *Flashlight Jigsaw* is another multi-player jigsaw puzzle with a wall display and three wireless handheld controllers (Cao et al., 2008). Each controller can reveal and move different jigsaw pieces. There are also hidden jigsaw pieces, which are only visible when controllers overlap with each other. Users have to collaborate, and only then, the puzzle can be completed. Fails et al. (2011) proposed *MobileStories*, a content splitting application for collaborative reading and sharing stories across two mobile devices. The configuration of the system requires users to collaboratively read stories together. Correspondingly, users interact, communicate, pay attention to others around them, and adjust themselves according to others' behaviors, throughout the activity.

3.6 Summary and Research Gap

This chapter presents different designs of technology in terms of how they are employed in co-located interaction. Mobile technology is utilized in this research domain, integrated with other technology, as well as standalone systems. The chapter provides four design objectives and example systems and designs that fulfill the objectives. These objectives are *inviting*, *facilitating*, *encouraging*, and *enforcing*. These objectives extend the design approach of Benford et al. (2000) and perceive them as objectives that guide researchers and

[5] http://www.sleepingbeastgames.com/spaceteam/

designers in designing mobile technology for co-located interaction. Mobile technology that *invites co-located interaction* usually attempts to initiate, trigger, and provokes face-to-face interaction between co-located people, by matchmaking users and providing information to enhance an encounter or trigger interaction. Mobile technology *enables co-located interaction* through multiple user interface design and connectivity between devices. Systems and designs with new application concepts are introduced to utilize the technology in different activities. Mobile technology *facilitates interaction* between users by creating shared displays, shared workspaces, and shared information/content pool to overcome form factor limitations of mobile devices. Mobile technology *encouraging* and *enforcing interaction* create constraints in an activity to engender interaction and collaboration. Constraints are used to formulate different incentives in order to motivate user to interact, collaborate, and accomplish the task in systems that encourage interaction. Users can still achieve the task without doing so. In contrast, users have to interact and collaborate to achieve the task in systems that enforce interaction.

This research looks at co-located interaction from broader perspectives than Benford et al. (2000). The focus is not limited to only shared interfaces and collaboration, but also separate interfaces and other forms of social interaction like encounters or competitions. Furthermore, research and designs of mobile technology in co-located interaction mostly aim to *facilitate interaction*, leaving little understandings in designing the mobile technology for other objectives (*inviting, encouraging,* and *enforcing interaction*). This thesis develops on prior works and further explores these less concerned objectives. This research identifies how different designs of mobile technology can help fulfill these objectives. Several design concepts are introduced for these three objectives and are evaluated with users. The outcomes of this thesis contribute to new knowledge and understandings of mobile technology and outlines potential roles that mobile technology can have in co-located interaction, while fulfilling these design objectives. Furthermore, this research also offers insights in design process, considerations, and how various designs are generated in order to guide researchers and designers working in this domain.

4. Research Approach, Process, Methods, and Ethics

This chapter presents research approach, process and methodology employed in the user studies reported in the papers included in this thesis. The goal of the thesis is to gain better understanding of mobile technology in co-located interaction. Based on the previous works presented in Chapter 3, four design objectives for designing mobile technology for co-located interaction are identified. However, to fill the research gap, user studies conducted in this thesis focus on three objectives - inviting, encouraging, and enforcing co-located interaction. The other objective (technology facilitates co-located interaction) has already gained much attention from researchers and designers within HCI and CSCW communities, thus, it is not the primary focus on this thesis.

4.1 Research Approach

This thesis is based on empirical research (Wobbrock & Kientz 2016). It seeks explanations of the user experience and to identify influencing factors in the designs of mobile technology that impact the user experience and practices. This research follows research through design (Zimmerman et al., 2007) as the main research approach in order to generate an understanding of mobile technology in co-located interactions. The approach enables research to address the interaction between users, the social implications, and the experience of technology through the uses of systems or prototypes (Zimmerman and Forlizzi, 2008).

The user experience and practices, which are central of this research, are inseparable from an individual and constructed as s/he engage with the world (Creswell 2013; Hookway 2016). Thus, all studies in the thesis are semi-structured qualitative studies (Blandford, 2013) and adopt an interpretivist analytic perspective (Ponterotto 2005). The studies produce qualitative data with qualitative research methods (interview, observation, focus group and user trial). Qualitative research allows researchers to not only evaluate the outcomes of users interacting with technology, but also understand the reasons behind their actions, feedback, motivations and the user experience. The quantitative method was utilized in one study to complement the qualitative results and compare the experience of before and after using a prototype.

Qualitative data was analyzed with qualitative content analysis (Elo & Kyngäs 2008), particularly conventional content analysis (Hsieh & Shannon 2005). Data was organized into categories in the form of an affinity diagram (Beyer & Holtzblatt 1998). The categories are induced and developed based on themes, patterns, understandings, and insights that emerged from the data itself. These outcomes are then formed into design implications and, later on, a model for designing mobile technology for co-located interaction.

4.2 Research Process and Methods

The thesis includes six studies, introducing seven conceptual designs of mobile application, a novel physical design of mobile device, and two working prototypes. Four studies focus on inviting co-located interaction. The other two studies focus on encouraging co-located interaction and enforcing co-located interaction, respectively. Empirical findings of these six studies produce understanding in consequences of different designs of mobile devices and applications concepts in interaction between co-located users (RQ1). The analysis of these findings in relation with the related work yield opportunities and considerations in designing mobile technology for the domain, including role of mobile technology in co-located interaction, design implications of each role, and a model for designing mobile technology for the domain (RQ2). Figure 1 summarizes the overall research process of this research.

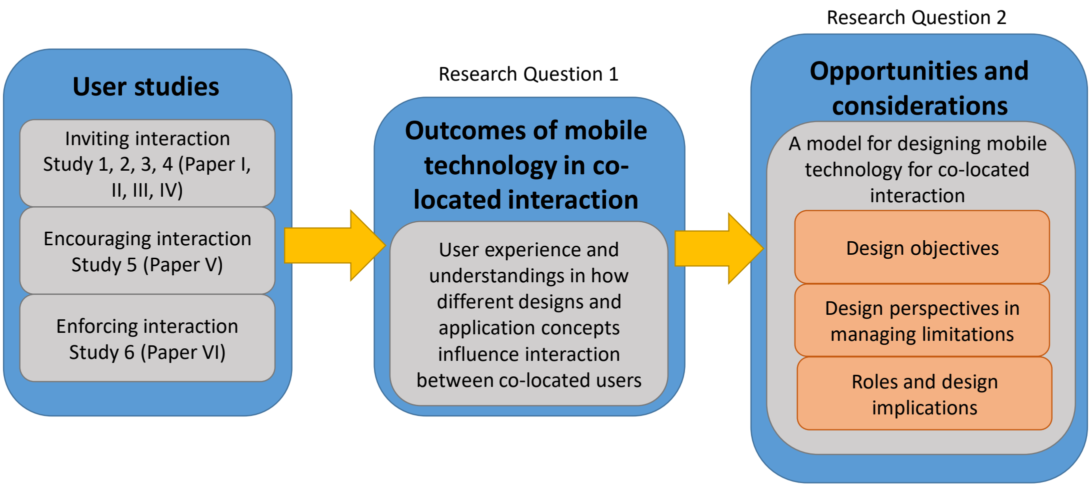

Figure 1: Overall Research Process

Altogether, 173 participants with multiple nationalities and backgrounds participated in the six studies. Study 1 explored the possibilities of different ticket-to-talk information in inviting interaction between strangers and familiar stranger. The study was based on illustrated scenarios and one-to-one interview. Study 2 introduced the concept of *Social Devices*, mobile devices adopting proactive characteristic with audio-based interaction modality, creating social triangulation to bring strangers together. Study 2 employed Wizard-of-Oz as a technique to simulate the situation. Study 3 and Study 4 explored the idea of *activity awareness* between surrounding people and mobile device user with the concept of *Social Display*. Social display went through two iterations of design, starting with focus group and co-design (Study 3). This was followed by implementing a working prototype and evaluating it in the field with users for 10-12 days (Study 4). Study 5 explored information asymmetry in encouraging co-located interaction, introducing *Who's Next*, a mobile multi-player game intended for an icebreaking activity. The game was evaluated in a user trial, which was followed by a group-based interview. Study 6 explored interaction asymmetry in enforcing collaboration in a photo taking activity. A user trial of three different photo-taking methods was conducted, followed by interviews. These studies identified different aspects of designing and consequences of mobile technology for interaction between users. Table 3 briefly summarizes all the studies conducted in this thesis. The following chapter further explains the studies with the detailed design and the major findings of each study.

Table 3: Summary of the user studies conducted in the thesis

	Design Objectives	Theoretical Foundations	Methods	Data Gathering	Analysis Method
Study 1	Inviting interaction	Ticket-to-talk (Sacks, 1992)	Scenarios, semi-structured interview	Audio records	Affinity diagram
Study 2	Inviting interaction	Social triangulation (Whyte, 1980)	Wizard of Oz simulation, semi pair structure interview	Audio records, Video records	Content analysis
Study 3	Inviting interaction	Awareness (Dourish and Bellotti, 1992; Raento and Oulasvirta, 2008)	Focus group, scenario, co-design	Audio records, Video records, participants' designs	Content analysis
Study 4	Inviting interaction	Awareness (Dourish and Bellotti, 1992; Raento and Oulasvirta, 2008)	Field trial, semi-structure interview, questionnaire	Audio records, pre- and post-questionnaire, daily questionnaire	Affinity diagram
Study 5	Encouraging interaction	Asymmetry (Björk and Holopainen, 2004)	User trial, semi-structure group interview	Audio records, Video records	Content analysis
Study 6	Enforcing interaction	Asymmetry (Björk and Holopainen, 2004)	User trial, semi-structure pair interview	Audio records, Video records	Content analysis

4.3 Research Ethics

This research follows the guidelines of Finish Advisory Board on Research Integrity (TENK)[6]. All the studies started with a written consent form. The consent presented that the participants were participating voluntarily, stated methods of collecting empirical data, and listed researchers who would have access to the data. It was described how the confidentiality or anonymity would be maintained. For all the studies, the participants were informed that participating in the studies is truly voluntary and they can stop the study at any time.

[6] http://www.tenk.fi/en

5. User Studies

This chapter describes in detail the studies conducted in this thesis. It includes design of concepts and prototypes, design decisions and theoretical foundations behind the decisions, research settings, methodologies, participant information, and findings from each study.

5.1 Study 1: Scenarios Study (Paper I)

This study is a scenario-based study of four different mobile application concepts, demonstrating three themes. These concepts aim to *invite interaction* between people who are co-located and within close proximity, but there is no face-to-face interaction between them yet.

5.1.1 Positioning and Design Approach

One way to invite interaction is by providing information as a stimuli or source of conversation for people. Sack (1992) defines this as a *ticket*, which is a polite reason for one to open or close an interaction with others, also known as a "*ticket-to-talk*." Drawing from previous work, the three themes include, 1) *informing who and what are around*, 2) *augmenting self-expression,* and 3) *online interaction encouraging physical interaction*. In the first theme, informing who and what are around, mobile technology provides information that augments the ordinary senses of users, e.g., what is going on around a campus or neighborhood or the frequency by which people encounter each other. The second theme, augmenting self-expression, provides digital content to augment physical appearance to facilitate face-to-face interaction. As compared to direct physical face-to-face interaction, online activity offers less resistance to start an interaction than a physical presence activity (Karahalios and Dobson, 2005). The last theme, online interaction encourages physical interaction, creates a "*play first, talk later*" kind of situation (Yoon et al., 2004). First, the design invites online interaction, and then develops the interaction into a face-to-face rendezvous.

This study attempts to identify potential of mobile technology in providing information for ticket-to-talk topics (Sacks, 1992) and interaction channels in different contexts (gym, neighborhood, third place (Oldenburg n.d.), such as a café, or during a bus ride) to bring people together and trigger face-to-face interaction. Contrary to previous work, this study is interested in not only first encounter between strangers, but also between familiar strangers – people who often meet, but never interact with each other (Milgram et al., 1992). This study contributes to Paper I.

5.1.2 Methodology

The ideas are presented through illustrated scenarios (Figure 2 shows excerpt from one of the scenarios) that describe the activities and contexts, in which the concepts will occur (Carroll, 2000). Illustrated scenarios are chosen instead of implementing working prototypes as a tool to communicate the ideas, because they allow exploring multiple ideas at the same time. Furthermore, to get these concepts working, it requires not only the development of resources and time, but also critical mass of active users. Scenarios shorten the timespan before the ideas or concepts reach the users. Although, scenario as a method has its own drawback - the results are based on *what people think about how they would use a technology, not how they actually use it*. Thus, often, feedback from users are their first impressions about the concepts, which may not be fully thought through. Moreover, many of users' opinions are heavily task-related, and only few mention non-task related opinions or playful activities, even though the scenarios are not task-focused concepts. Nevertheless, despite the limitations, scenario study helps in identifying opportunities, frame the scope of design and identify weakness of concepts, before starting the actual development.

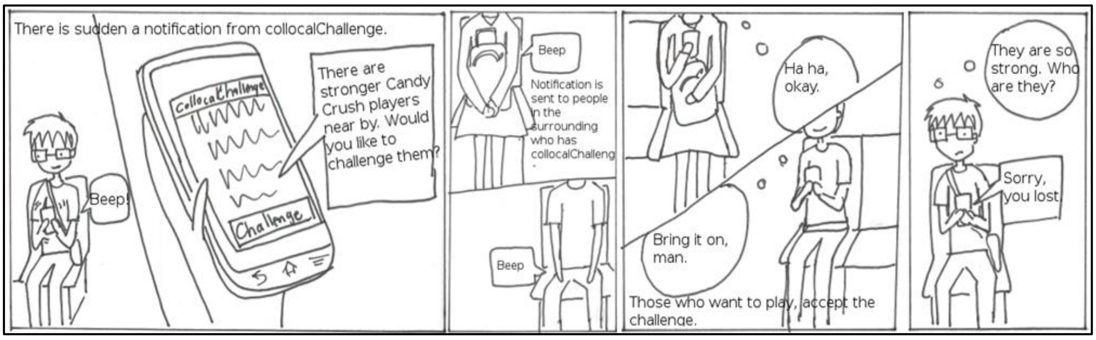

Figure 2 Excerpt (4/14 Screens) From One of the Four Scenarios

5.1.3 Procedure, Data gathering, Data Analysis, and Participants

Forty-two semi-structured one-to-one interviews were conducted with illustrated scenarios as discussion stimuli. Each participant was presented with one scenario, chosen by the researcher, based on his/her answers in the background recruitment survey for the study. Interview sessions started with the researcher presenting a printed scenario. This was followed by semi-structured interview for 20-40 minutes. Interviews were audio recorded for later transcription and analysis. The interview transcripts were analyzed with qualitative content analysis (Hsieh & Shannon 2005), in particular with a bottom-up identification of the hierarchy of themes on Nvivo application, carried out together by three researchers. The study involved 42 participants (26 males and 16 females), aged between 22 to 37 years (average 26.3). Participants were international, from 16 nationalities with Finnish and

Chinese as top two ethnic groups. Most of the participants were master or doctoral university students.

5.1.4 Findings

The illustrated scenarios provide different forms of ticket-to-talk to invite a face-to-face interaction between people in different contexts. Merely providing information can potentially invite face-to-face interaction if the chuck of information contains common ground between users, is mutually given to users, and they are aware that all the other users know about it. Ticket-to-talk topics that provide information to inform who and what are around can provide opportunities beyond people's existing social circles or act as a channel for users to ask for practical helps from those within close proximity—i.e., when people are nearby but cannot see each other. Furthermore, it provides information, which users consider as good to know information and increase awareness about things that are going around them. Possible design space for mobile technology inviting face-to-face interaction is for hobby-related activities that require several people (e.g., sports or musical band). However, the potential for inviting face-to-face interaction is still doubted for pure social activities like a party. Users were worried about awkward situations and security issues that may occur in an encounter.

While online self-expression can trigger online interaction between friends, augmenting physical presence with online personal self-expression was found to be ambiguous and dull to invite face-to-face interaction between strangers within the same space. An online activity, playing a game, can possibly trigger face-to-face interaction between strangers and acquaintances. However, it is more suitable as an icebreaking activity in a social event or gathering, where people are going to spend a long time together instead of bringing two random strangers together.

Context is a significant factor identifying potential mobile technology offering ticket-to-talk topics in triggering or inviting face-to-face interaction. A place familiar to users or hobby-related activities are promising contexts for mobile technology to invite face-to-face interaction between strangers.

5.2 Study 2: Proactive Audio-Based Mobile Device Study (Paper II)

This study introduces and evaluates a socially proactive system called *Social Devices*. Social Devices aim to invite interaction between two users, unfamiliar to each other by using speech-based output to interact between two devices and users.

5.2.1 Positioning and Design Approach

This study adopted the concept of social triangulation (Whyte, 1980) to *invite interaction* between strangers in an encounter. Social triangulation is external stimuli that provide a connection between strangers within a given space (ibid). Stimuli can refer to a statue, a performance of a clown, or any technology in a public place. Here, the stimulus is mobile devices embracing proactive characteristics. Proactive computing limits the degree of user involvement and explicit user input by shifting the overall approach from being human-centered to human-supervised. Users only provide system with their overall goals (Tennenhouse, 2000). In this study, mobile devices are being proactive in a social setting, triggering interaction between two strangers. Mobile devices start to interact with each other, trying to involve the two strangers in an interaction, and propose safe and neutral conversation topics. Audio-based interaction, both speech and non-speech, is the interaction modality between users and the devices, as well as amid the devices. The modality generally supports an activity to be done in parallel with others, i.e., enabling peripheral, hand-free, and eye-free interaction (Sawhney and Schmandt, 2000). Furthermore, it is publicly observable and creates experiences that can be easily shared and sensed by proximal people. Mobile devices with this proactive character stimulating an interaction through audio-based output are referred as *Social Devices*. This study attempts to identify potential of mobile devices with these qualities in inviting co-located interactions. This study contributes to Paper II.

5.2.2 Methodology

The concept of *Social Devices* is simulated with Wizard-of-Oz technique (Dow et al., 2005). The method imitates functions and behavior of technology as if they work entirely. In reality, those functions and behaviors are simulated to react properly by a researcher who closely observes user's actions. This simulation allows participants to experience a working system without the system has to be fully developed. The main feature of *Social Devices* in this study is that the devices automatically play music and speak to each other. Music and speaking lines are pre-generated audios. These lines are basic small talk dialogues. A researcher, who acted as a wizard, selected a specific line to play, based on the participants' actions and answers during the simulation in real time. In addition, this study also simulated first encounter between two strangers with *Social Devices* in a semi-public place. Encounters between users carrying *Social Devices* (in case the concept is fully implemented) in real life will be difficult to observe for the researchers. This was made possible in the simulation.

For the Wizard-of-Oz study, mobile devices were provided to the participants. These devices had a specific application installed, which allowed the researcher to operate the devices. The participants did not own mobile devices used in the study. To simulate the encounter with *Social Devices*, participants were scheduled to come to the study, but not meet each other until they were provided with the devices. Then, they were asked to wait in a prepared location, where they encountered another participant. *Social Devices* were activated right after the two participants met each other. This simulation did not fully imitate a real encounter between strangers, but it allowed the participants to experience *Social Devices* at some levels. It also allowed communicating the concept of *Social Devices* to the participants better than the scenario-based description.

5.2.3 Procedure, Data gathering, Data Analysis, and Participants

Twenty-three study sessions were conducted. Due to some technical problems, there were eighteen valid sessions. In each session, participants were paired with another participant to simulate an encounter. Pairing participants with the same nationality was avoided to prevent non-English discussions during the simulation. A session began with the encounter and Wizard-of-Oz simulation. The simulation lasted 5-10 minutes depending upon how active participants were in interacting with each other. Figure 3 shows examples of the study setting and interaction between participants during the simulation. This was followed by semi-structured paired interview, discussing participants' experiences and opinion about *Social Devices*. The interviews lasted for a duration of 45 to 60 minutes.

Figure 3: Example Study Setting and Interaction between Participants (12 of 18 Valid Sessions)

The study produced two sets of data - video recordings of participants' actions in the simulation and audio recordings of the interviews. The video recordings were transcribed and coded systematically, based on the emerging interaction practices between users themselves and users and *Social Devices*. Audio transcripts were analyzed with a physical affinity diagram, producing a data-driven and bottom-up hierarchy of themes (Beyer and Holtzblatt, 1998). The study involved 45 participants (31 males, 14 females) with different nationalities, and aged between 18 to 51 years, with an average age of 26 years. Participants were from 16 different nationalities, with the most prominent nationalities (more than 4 participants) being Finnish, Pakistani, Indian and Chinese. The participants were bachelors, masters or doctoral level university students, recruited from mailing lists and the intranet of the local university.

5.2.4 Findings

This study explored potential of proactive and audio-based interaction in mobile devices to trigger face-to-face interaction through a simulation with Wizard-of-Oz. While *Social Devices* did trigger interaction between most of the participants, they did not entirely appreciate the system. *Social Devices* engendered face-to-face interaction, which otherwise might not have taken place. Proactive characteristic was the key aspect that trigger interaction between participants. However, participants prefer to have control over the proactive characteristics to avoid the devices leading to an undesired or awkward situation. Audio-based output is good for catching attention and creates a mutual understanding about the situation between participants. However, it is easily missed and requires a lot of attention in a noisy environment. Furthermore, *Social Devices* were considered to be too active and dominant in the simulated situation, which at times inhibited existing and emerging face-to-face interaction between participants. Often, interaction between participants heavily relied on behavior of *Social Devices*. Nevertheless, *Social Devices* did not only undertake the position of an interaction trigger, but also as an interaction facilitator, which encouraged interaction and collaboration between participants throughout the simulation.

5.3 Study 3: Social Display – Focus Group (Paper III)

This study is a focus group study of a new concept known as *Social Display*. It aims to increase awareness about the activities of mobile device users to others in physical surroundings through an extended display on the backside of the mobile devices. The increased awareness is anticipated to invite interaction between device users and others around them, allowing others to initiate an interaction based on the mobile device users' activities.

5.3.1 Positioning and Design Approach

Private characteristic of mobile devices has decreased the awareness the surrounding others have of mobile device users' activities (Turkle, 2011). Consequently, opportunities for serendipitous interaction around the activities may have diminished. For example, reading a newspaper allows the others to see what one is doing and even ask about the content. Similarly, browsing photos or watching videos on mobile devices has lost the social elements that physical photos or televisions usually have (e.g. a joint focus or a shared interface).

Awareness of others has been defined as “understanding of the activities of others, which provides a context for your own activity” (Dourish and Bellotti, 1992, p.107). Raento and Oulasvirta define social awareness application as “the idea of a group sharing real time context information via a personal and ubiquitous terminal” (Raento and Oulasvirta, 2008, p.527) Remote awareness systems encourage serendipitous interaction (Dourish and Bly, 1992; Church et al., 2010). This study explores the potential of awareness in co-located interaction, focusing on the awareness that co-located people have about the activities of mobile users on their devices. This awareness is referred as *activity awareness*. The concept of *Social Display* is also introduced as additional displays on mobile devices automatically provide social cues about the activities of a device user to surrounding people. This study identifies early design consideration of Social Display as a social awareness application. Findings from this part of study contribute to Paper III.

5.3.2 Methodology

Focus group discussion was conducted in order to explore the concept of Social Display. Four illustrated scenarios demonstrated different use cases of Social Display were presented to participants (Figure 4 shows excerpts from the scenarios). The scenarios varied in social situations, relationships with others in the surroundings, and activities on mobile devices. This diversity intended to help the participants to form broad understandings of the concept and encourage discussion from various points of view. Group discussion also allowed participants to develop their opinions and reflections and offer broader understandings and viewpoints of the concepts (Lazar et al., 2010). The discussion was mainly about practicality, opportunities, and challenges of the concept. Additionally, to encourage participants to think through the concept further, each session of the study included co-design activity, where participants had to design how their activities on mobile device would be presented to others on Social Display. This allowed researchers to receive potential users’ insights, example use cases and design contents, which reflect participants’ expectations of the concept. Mobile devices were provided with screen captures of different mobile applications attached to the front display as stimuli, e.g., news, social network services, leisure and entertainment, etc. (Figure 5: left). Participants were encouraged to consider different contexts of use, and how these contexts affect their design decision of content on Social Display.

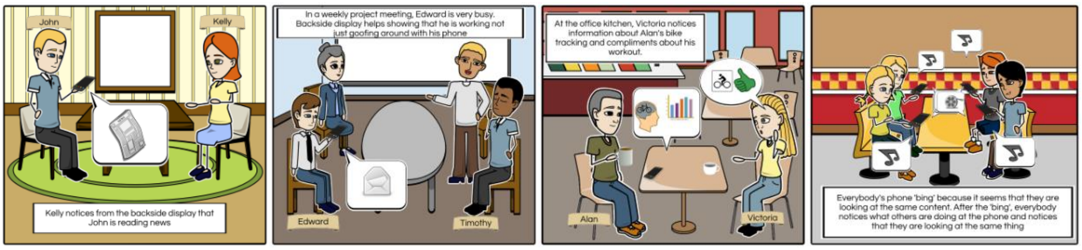

Figure 4: Excerpt from Illustrated Scenarios. From left to right, the context is within a family, with colleagues in formal setting, with colleagues in casual setting, and with friends

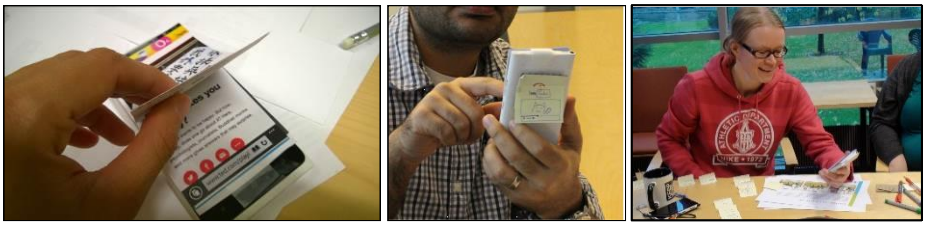

Figure 5: Mobile devices with screen captures attached to the front display as stimuli for co-design. Middle and right: participants presenting their design of content on Social Display

5.3.3 Procedure, Data gathering, Data analysis, and Participants

Five focus groups were conducted with 4 to 6 participants per group. Each session started with an introduction to the concept of Social Display, followed by the possible use cases of Social Display with illustrated scenarios. All scenarios were presented to all the participants. There was a time slot after each scenario for participants to discuss their opinions. After the presentation of all the scenarios, participants were asked to compare them and choose their most and least favorite, based on practicality and comfort of having Social Display in such contexts. The scenario discussion lasted approximately 90 minutes and was followed by individual co-design activity. Then, each participant presented his/her design to the group (Figure 5: middle and right). The co-design activity lasted approximately 45 minutes. All the sessions were audio recorded and transcribed. The transcripts were analyzed with qualitative content analysis (Hsieh & Shannon 2005), particularly with a physical affinity diagram that produced a data-driven and bottom-up hierarchy of themes. Altogether, 23 participants participated in the study (11 males and 12 females). The age distribution was between 23 to 46 years, with an average age of 29.5, and represented a wide variety of nationalities (13 nationalities, with Finnish as the most common).

5.3.4 Findings

This study introduced the early concept of Social Display, increasing mobile activity awareness by using an additional display attached to the backside of mobile devices. Social display was identified to be a promising source for starting a conversation, allowing not only mobile device users, but also those around them to initiate interaction related to an activity or content on mobile devices. Furthermore, it was also seen as a tool to fight the formation of private bubble, allowing others in the surrounding to encourage mobile device users to focus on a physical activity around them.

Balancing between increasing activity awareness and self-presentation is generally a major concern of Social Display. Using mobile devices seem to render some activities to be perceived as more private than using traditional artifacts. Participants indicated a desire to control the content on Social Display depending upon social situations, relationship with others in the surroundings, and their activities on mobile devices. They suggested variation of designs in co-design sessions to cope with this issue. An icon and a name of a currently active application was a common design choice for the content to be automatically presented on Social Display. User-generated content or an option to remove certain activities from Social Display was an alternative design that enables user to retain control of the content.

5.4 Study 4: Social Display – Field Trial (Paper IV)

This is a continuation of scenarios and co-design study of Social Display. The concept was later implemented as a working prototype. This study explores potential of Social Display in increasing activity awareness and analyzes consequences of Social Display on mobile device users and others around them.

5.4.1 Positioning and Design Approach

This study develops the concept of Social Display into a working prototype. Social display prototype consists of a mobile application (Social Display application) and an e-ink display (Social Display). The display shows icon and name of the application that is currently active on the mobile device. The design of content on Social Display is based on a common design from participants in Study 3. Social display is attached to the backside of mobile device. There is a hinge between the backside of the mobile device and the display to keep user from covering the display with his/her hand, maximizing its visibility to surrounding people (see Figure 6). This study contributes to paper IV.

Figure 6: Social Display Prototype. A hinge allows user to hold the device without covering the display

5.4.2 Methodology

A field study of the prototype was conducted. Participants had the prototype attached to their own mobile devices for 10-12 days and used the prototype in their daily routine. Due to the length of the trial period, constant observation of the participants was not feasible. The findings are primarily based on the participants' reports of their experiences and discussion with some of the people they encountered. Daily questionnaire was sent to the participants through emails, which they filled it in online. The questionnaire was sent daily instead of asking them to fill in a dairy, in order to avoid the chance of participants forgetting to fill the diary on a daily basis and only try to fill it in on the last day of the trial. The daily questionnaire included questions about participants' experience, their behaviors, and feelings while using the mobile devices with Social Display, as well as the behavior of people around them regarding Social Display. The questionnaire helped collect experience that participants might have already forgotten by the time of the post-trial interview. Researcher looked through all the answers from daily questionnaire, before the post-trial interview. Interesting answers were further discussed during the post-field trial interview. Additionally, because Social Display is not only about mobile device users, but also about those around the users. Mobile device users are only information providers; others around the users are those who actually view the Social Display. Thus, a questionnaire and short interview was also prepared for the people who participants occasionally encountered during the trial period. The questions were related to their impressions and potential of Social Display in increasing activity awareness.

5.4.3 Procedure, Data gathering, Data analysis, and Participants

The field trial was conducted with 13 participants. Each trial began with introduction to the concept of Social Display, pre-field trial one-to-one semi-structured interview, and pre-field trial questionnaire. Pre-field trial interview included questions about participants' general attitude and behavior regarding privacy, their use of mobile devices in daily life, and their first impression about Social Display. Then, the prototype was installed on participants' mobile devices. Daily questionnaire was sent to the participants in the evening during the trial period. Post-field trial meeting took place after 10 to 12 days of the prototype installation. The meeting included another round of one-to-one semi-structured interview and post-field trial questionnaire. Post-field trial interview was about participants' experience and influences of Social Display during the trial. Pre- and post- trial questionnaires had the same set of questions, but from before and after the field trial perspectives. Questions were related to the impression regarding Social Display, expectation and actual experience with the prototype, and privacy-related issue. All interviews were audio recorded and transcribed. Qualitative data from the interview and questionnaires were analyzed following the procedure of affinity diagram process (Beyer and Holtzblatt, 1998) with a digital tool—Microsoft Excel. Three researchers analyzed the data independently. The insights were then discussed to form a common understanding and categories. For quantitative data, no advance analysis was conducted; only basic comparisons between pre- and post-field trial answers.

The 13 participants included seven males and six females, represented seven different nationalities (Finnish being the most common – 6/13), their ages ranging from 21 to 42 years old (average 26). The recruitment of the participants was done on a voluntary basis via email lists and bulletin boards at the university. The participants were selected based on a screening survey that inquired how active they are as mobile users and how much they engage in various social activities. The minimum requirements were that the participants are active smartphone users and socially active in their everyday lives. The chosen participants of this field trial in general were familiar with sharing their mobile device activities with others, to some extent and used mobile devices during their interactions with others.

5.4.4 Findings

The field trial shows that Social Display was able to increase activity awareness. While Social Display is still far behind in providing activity awareness to the same level as traditional artifacts (e.g., newspaper, books, or television), others in the surrounding at least had a brief idea about user's current activity on mobile devices. Social display was visible to others around the device users, and it was not considered impolite for others to look at the Social Display.

Often, activity awareness from visual cues on Social Display provides merely good-to-know information. This does not always result in interaction between mobile device users and co-located others. Sometimes, others were curious about device user's activity presented on Social Display and resulted in a conversation. This usually happens only between users and their families and friends. Social display underlines user's activities with mobile devices, thus, raises user's self-awareness regarding appropriateness of using mobile devices in a certain context. This appropriateness was considered based on three factors - application being used, ongoing situation, and relationship between the device user and others around them.

5.5 Study 5: Who's Next – Multi-player Game for Icebreaking Activity (Paper V)

This study introduces and evaluates a multi-player game, known as *Who's Next*. This is a mobile quiz-based game. The game is designed to facilitate a group of strangers in getting to know each other in an icebreaking activity, aiming to encourage interaction between them.

5.5.1 Positioning and Design Approach

This study explored potential of mobile technology in mediating and encouraging co-located interaction in an activity, specifically an icebreaking activity. Icebreaking is an activity intended to get people to know each other, creating a friendly atmosphere, encouraging collaboration and participation between people (Dixon et al., 2006; Parsell, 1998; West, 1999). Typical icebreaking activities often face issues such as an individual dominating group activity, participants not feeling comfortable interacting with strangers, etc. (Dennick and Exley, 2004).

While results from Study 2 (*Social Devices*) shed light on the potential of mobile devices in encouraging interaction and collaboration between strangers, involving mobile technology in a co-located activity can potentially lead to *private spheres* (Szentgyorgyi et al., 2008). This, thus, creates an interesting design space to explore the position of mobile technology, especially in the context of social interaction and interaction between participants as a primary focus. *Who's Next*, a multi-player, multi-device quiz-based game, is introduced to facilitate getting to know each other and creating a friendly space for interaction. It is intended to be used in the first encounter of a small group of strangers, offering an alternative solution for self-introduction between group members. *Who's Next* draws inspiration from a party game, *Truth or Dare*[7], and gamifies self-introduction and utilizes information asymmetry technique to encourage interaction between players. Information asymmetry is a situation in which each user has a different set of information, and all the sets are required to achieve a goal in an activity. This technique is commonly employed in games. Björk and Holopainen (2004) have described this as a form of gameplay design pattern, which can lead to collaboration and competition between players.

[7]http://en.wikipedia.org/wiki/Truth_or_Dare%3F

Zagal (2006) further states that while collaborative game can easily be dominated by a single player, information asymmetry is a technique to keep players collaborated with each other. *Who's Next* utilizes the content related to the player themselves as information asymmetry, which amongst strangers, or even acquaintances, this personal information is unknown. This study identifies potential of mobile technology in co-located interaction, employing information asymmetry to encourage interaction between users. This study contributes to Paper V.

5.5.2 Methodology

Who's Next is fully implemented as a working prototype and was evaluated in six sessions of group-based user study. Participants, mostly strangers to each other, played the game for three rounds with two different sets of questions. The first round was only for the participants to become familiar and understand the concept of the game. Participants were interviewed in a group with semi-structured questions. The findings from the study consist of researchers observing users' actions complemented with subjective opinions and experiences. While it is possible to conduct a study in a context similar to the target context, i.e., mobile game for icebreaking purpose, it is not possible to do the comparison study between non-technology mediated activity and technology mediated activity with the same group of participants. This is because participants would have already become comfortable with each other after an icebreaking activity, either technology-mediated or non-technology-mediated approach. It is impossible to go back to the state when they were unknown and uncomfortable with each other. Furthermore, people act differently base on situations and others around them (Goffman 2008). Different groups may interact differently base on types and personalities of group members. Thus, this study did not compare technology mediated and a typical icebreaking activity bit by bit, but address differences base on participants' previous experience in the activity domain.

5.5.3 Procedure, Data Gathering, Data Analysis, and Participants

Six sessions of user study were conducted with 4 to 6 participants per session, where all the participants played *Who's Next* game in a group. Mobile devices were provided for every participant in each of the sessions. The game began with participants answering a pre-defined list of questions (Figure 7: left), followed by the actual game. The goal of the game is to find out the person behind the given answer of a question (Figure 7: middle). The game is turn-based, thus, there is a single active player and others have to wait for their turns (Figure 7: right). Each round of the game lasted for 5 minutes and three rounds were played. This was followed by a group-based semi-structured interview. All activities throughout the game and interview were video and audio recorded for later analysis. Two researchers also took note about emerging interaction patterns between participants. These interaction patterns were also discussed during the interview with participants. Each session lasted for an hour, of which playing the game took about 20 minutes. The video recordings were transcribed and coded based on the interaction patterns that emerged between participants during the game. The audio recordings of the group discussions were transcribed in verbatim. Both video and audio records were analyzed with qualitative content analysis (Hsieh & Shannon 2005), particularly with an affinity diagram (Beyer and Holtzblatt, 1998) that produced a data-driven and bottom-up hierarchy of themes.

Altogether 28 participants (16 males and 12 females) participated in the study with ages ranging from 22 to 36 (average: 27) and representing a broad variety of 16 different nationalities. The recruitment of the participants was made via bulletin boards at the local university and participation in the study was voluntary. They were invited to the session without any particular goals in the mind, beyond trying out a new multiplayer game. Most of the participants (20/28) reported being familiar with icebreaking activities and occasionally participated in such activities. General icebreaking activity concepts were explained to those who were unfamiliar with the concept.

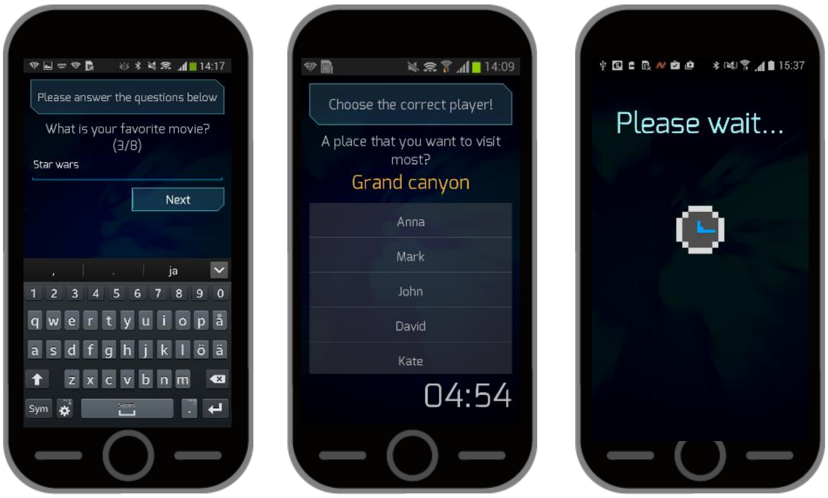

Figure 7 Left: An example of questions every player has to answer in the beginning; middle: an active player has to choose which of other players has given this particular answer to the question; right: other players screen when waiting for their turns

5.5.4 Findings

Who’s Next was found to be a promising tool to encourage and facilitate icebreaking activity in a situation where groups of strangers are getting to know each other. Even though participants only played the game for three rounds, significant changes in the group atmosphere, interaction pattern, collaboration between participants as well as interesting strategies participants appropriated through the game were observed in several sessions. Participants were more relaxed and open to each other during and after they played the game. Some answers to the questions led to conversations between participants. It also brought up topics that otherwise they might not have talked about. Information asymmetry within the game encouraged interaction between participants, as well as created playful situations, e.g., bluffing. Furthermore, *Who's Next* also facilitated self-introduction and provided a broader interaction space for different types of participants. That is, participants could position themselves in the level that is comfortable for them, while they could still share something about themselves. The user trial has shown that mobile technology can serve as a facilitator in a social activity. In *Who's Next*, mobile technology enforces rules for the activity. This reduced unnecessary meta-interaction with a human-facilitator, allowing participants to focus on the activity and interaction with other participants.

Mobile devices and information asymmetry design complement each other in encouraging co-located interaction. In addition to personal information, which is usually unknown to newly met strangers, personal nature of mobile device also allows a question to be presented to only one user at a time. This encourages the user to read aloud the question, which often initiates a short interaction among the participants. Furthermore, asymmetry information keeps users engaged to the activity, even if it was not their turns, encouraged contribution from everybody in a group, encouraged users to pay attention to those around them and the group as a whole to move along with the activity together.

5.6 Study 6: Collaborative Camera (Paper VI)

This study introduces a novel photo taking method, which turns a typical solitary photo taking activity using mobile camera phone into a collaborative activity. In this method, a pair of users act as a single camera, where one user is a camera trigger and another is a viewfinder. This photo taking method is compared with other two traditional methods in this study. The aim of this method is to enforce interaction between users and explore consequences concerning user experience in the activity.

5.6.1 Positioning and Design Approach

Photo taking is one of the most common uses of mobile devices (Smith, 2011). Despite the fact that photos are social artifacts (Frohlich et al., 2002; T. Kindberg et al., 2005; Tim Kindberg et al., 2005), interactions around photos usually happen only after a photo is captured. While several professional photographers actually collaborate on photographing (e.g., Inez and Vinoodh[8] or Bernd and Hilla Becher[9]), this collaboration is not as common with mobile camera phones. Ploderer et al. (2012) argued that the process of photo taking

[8] https://en.wikipedia.org/wiki/Inez_and_Vinoodh
[9] https://en.wikipedia.org/wiki/Bernd_and_Hilla_Becher

itself can provide satisfaction and thus should not be overlooked. This study applies the technique of interaction asymmetry to pair-photo taking with mobile devices, in order to enforce collaboration within a pair and explore how this would influence the activity, interaction practices, and user experience. Similar to information asymmetry, interaction asymmetry is also common in games, and is used to encourage or enforce collaboration and engagement (Björk and Holopainen, 2004; Zagal, 2006). Interaction asymmetry emphasizes on different users having different interaction abilities. A simple example is hide-and-seek - the seeker seeks, and the others hide. These asymmetrical interaction abilities in pair-photo taking method are studied and compared with other two traditional photo-taking methods. The study identifies aspects to consider when employing interaction asymmetry to enforce collaboration with mobile technology and consequences of interaction asymmetry in enforcing interactions between users. This study contributes to Paper VI.

5.6.2 Methodology

A user study was conducted, where participants in pairs used three different methods to take photos together. These methods included: 1) both have their own devices — Separate Cameras; 2) only one device in a pair—Shared Camera; and 3) two devices with asymmetric abilities demanding both devices to take part in photo taking — Collaborative Camera. Participants had own cameras and took photos in a typical fashion in the Separate Cameras method. Participants shared a single camera in the Shared Camera method. The last method, Collaborative Camera, employed asymmetrical interaction abilities. Two devices performed as a single camera, one device was a viewfinder, and another was a trigger. Both devices displayed the same content of the photo being captured. Figure 8 summarizes all the methods in this study. All methods utilized mobile devices as camera apparatus. First two methods, Separate Cameras and Shared Camera, utilized default camera application provided on Android smartphones. Collaborative camera utilized an application available on Google Play Store, RemoteShot[10]. The application allows using one device as the viewfinder and another as the trigger. "*Things I would like to remember about this city*" was a theme given for this photo taking activity to provide a meaningful task for participants. This theme is based on one of the most common uses of camera phones – to record memories (Van House and David, 2005). However, the participants could modify the focus based on their personal interests.

[10] RemoteShot: https://goo.gl/WCOm9y

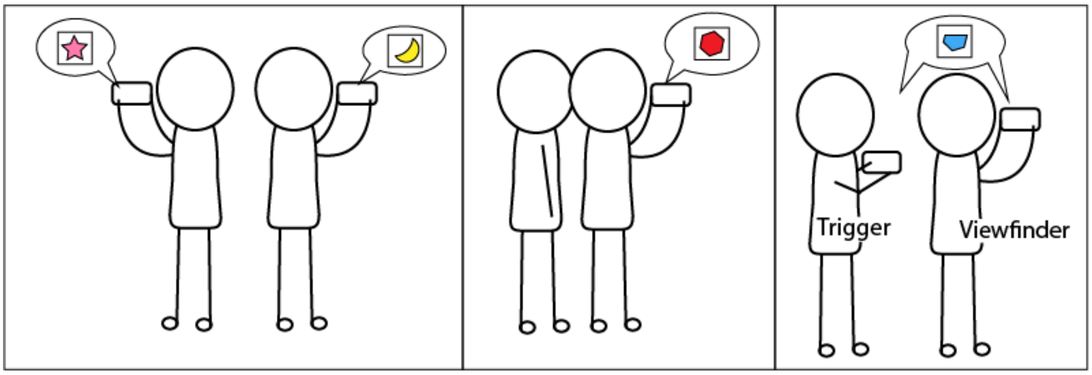

Figure 8: Summary of photo taking methods. Left: Separate Cameras; Middle: Shared Camera; Right: Collaborative Camera

5.6.3 Procedure, Data gathering, Data Analysis, and Participants

Eleven sessions were conducted in this user study. Each session began with a semi-structured interview in pairs, regarding the participants' practices in taking and sharing photos. The interview was audio recorded. This was followed by photo taking activity, where participants walked around nearby area to take photos using all the methods. The order of the methods was random. Each pair had approximately 15 minutes to take photos with each method. A researcher followed the participants around and video recorded their photo taking activity and tried not to affect the interaction between participants. Photo taking activity lasted for 45 minutes. This was followed by a short discussion about photos taken and semi-structured interview about participants' opinions and experience with different photo taking methods. This interview was video and audio recorded. The audio recordings were transcribed in verbatim, and the video recordings were analyzed to identify details of interactions, during the photo taking activities - sequence of activities and interaction between participants before, during, and after a photo was taken. Both video and audio records were analyzed with qualitative content analysis (Hsieh & Shannon 2005), particularly with an affinity diagram (Beyer and Holtzblatt, 1998) that produced a data-driven and bottom-up hierarchy of themes.

Altogether 22 participants (11 males and 11 females) participated in the study. The age range was between 18 to 36 years, with the average age of 26. Participants represented nine different nationalities with Finnish as the most common ethnic group. The recruitment of the participants was done via a bulletin board through the university intranet. The volunteers were asked to bring along one person as a partner for the study in the registration. Otherwise, they would be paired with another participant. Thus, most of participants in pairs knew each other. Relationships between participants vary from being colleagues to couples. Only three pairs were strangers. All participants reported using smartphones with cameras in their daily life and most of them frequently used their phones to take photos.

5.6.4 Findings

Photo taking methods affected photo taking practices, interaction, and collaboration between the participants in pairs. In Separate Cameras, participants were mostly on their own, when they were taking photos. Interactions between participants usually took place after a photo had already been taken or while walking to the next location. Participants stayed together more in Shared Camera method than in the Separate Cameras method. However, the collaboration and engagement in photo taking with Shared Camera was highly dependent on the participants' eagerness to do so. Interaction practices with these two methods were diverse from one pair to another. Participants found it best to synchronize their photo taking with the Collaborative Camera method.

Nevertheless, photo-taking methods are not the only factor for these different practices. They were also influenced by social aspects such as relationship between participants, habits of photo taking, attitudes toward collaboration, as well as personal photo taking skills. This led to different perceptions towards the activity and engendered different photo taking strategies. However, asymmetric interaction abilities in Collaborative Camera reduced effects of these social factors by assigning a role for each user within a pair. Interaction asymmetry forced participants to reposition themselves in the activity, for example, to communicate, collaborate, and come up with a common agreement to perform the task, which was a new practice for some participants. Consequently, photo taking practices and interaction patterns between pairs were less diverse in the method that employed interaction asymmetry (Collaborative Camera), as compared to other methods (Separate Cameras and Shared Camera).

Interaction asymmetry is found to be a promising approach to burst the mobile bubble at least in a creative small task, like photo taking. However, this requires a balance in the required attention and engagement between interacting with other users and completing a task responsibly. Furthermore, interaction abilities assigned to the users should be equally important to keep the users engaged in the activity.

6. Results

This chapter presents the main results of the thesis. The chapter is divided into two sections. The first section presents a model for designing mobile technology for co-located interaction. The model presents the relationship between research and design process of the thesis and the findings from the user studies. The second section presents design implications in designing mobile technology for this domain. These design implications are based on the insights and understandings gained throughout the studies and the reflections of outcomes in the light of existing literature.

6.1 A Model for Designing Mobile Technology for Co-located Interaction

This research demonstrated the research and design process in designing mobile technology for co-located interactions. This includes various application concepts and prototypes, theories and knowledge behind the concepts, and empirical findings of the concepts from user studies. Insights and understandings from this process are conceptualized into a model for designing mobile technology for co-located interactions. The model consists of three design aspects: 1) design objectives, 2) design perspectives in managing limitations of mobile devices, and 3) roles (Figure 9). The design objectives were introduced at the beginning of this research. These objectives are themes emerged from the literature review of existing mobile technology in combination with the design approaches of Benford et al. (2000) for collaborative interaction on shared interfaces. The design perspectives and the roles are novel design aspects, synthesized from the empirical findings of the studies conducted in this thesis and reflections with related work. The model is intended to guide researchers and designers in *how to design mobile technology for co-located interaction* - promptly identifying the position of mobile technology in co-located interaction before proceeding to design detailed attributes or design qualities of the user experience. For example, Lundgren et al. (2015) provided a design framework, which includes multiple design perspectives and properties. Instead of randomly selecting a few properties for ideation, the model can highlight properties that are relevant for the context mobile technology it is being designed for.

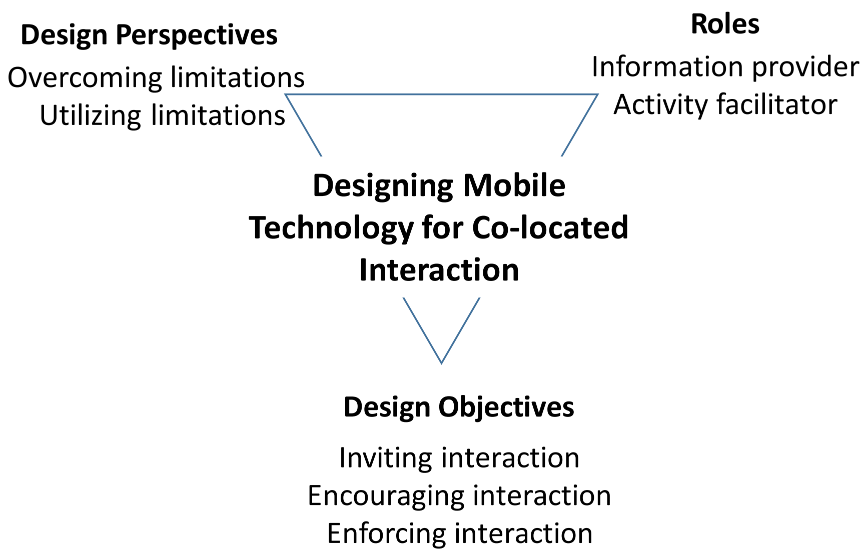

Figure 9: A Model for Designing Mobile Technology for Co-located Interaction

The design aspects identify three different perspectives that researchers should consider when designing mobile technology for co-located interaction. *Design objectives* consider a broad view of a design and the purposes of technology being involved in an interaction. They can guide the overall design directions, which impact the choice of theoretical foundations employed to support the design decision of the concepts being introduced. For example, Study 4 invited interaction by extending the concept of awareness (Dourish and Bellotti, 1992). *Design perspectives* consider how to manage the inherent limitations of mobile technology and technological behavior in a design, i.e., what technology should offer or constrain in an interaction. For example, Study 3 and Study 4 utilized a second display on the backside of a mobile device. This second display is used to overcome limitations of mobile devices, i.e., being small and personal, in order to increase awareness and invite interaction. Study 6 utilized the personal nature of the mobile device to assign different abilities to users to enforce interaction. Lastly, the roles consider the social behaviors of mobile technology for co-located interaction and how technology should be designed to enact such behaviors. For example, in Study 5 mobile technology acted as an activity facilitator; thus, it should have certain behaviors, like enforcing rules or giving instructions.

The following subsections further describe each design aspect in detail. Section 6.1.1 presents the summary of empirical findings with respect to the three design objectives already defined in literature and refined in this thesis. Section 6.1.2 presents two *design perspectives* as novel design concepts, related to technological behaviors in handling limitations of mobile technology. Section 6.1.3 presents the two *roles* as other novel design concepts concerning social positions of mobile technology for co-located interaction.

6.1.1 Design Objectives and Design Concepts

In this research, design objectives are set as design goals. All the studies aimed to fulfill one of these design objectives. Mobile technology was involved in co-located interaction with intentions to *invite*, *encourage*, or *enforce* interaction. This thesis produced five distinct design concepts. Six studies were conducted based on these concepts. Most of the concepts focused on mobile technology enhancing co-located social interaction (Study 1-5) and one study (Study 6) explored mobile technology and social interaction, together, enhancing activity experience. Table 4 summarizes relationship between design objectives and design concepts in this thesis. The following describes the *outcomes from introducing mobile technology in co-located interaction, including emerged interaction patterns and user experience* (RQ1) based on the design objectives of mobile technology for co-located interaction.

Table 4: Summary of design objectives and design concepts of mobile technology in this thesis

Design objectives	**Design concepts**
Inviting interaction	Engender ticket-to-talk (Study 1, Paper I)
	Engender social triangulation (Study 2, Paper II)
	Increase activity awareness with additional display (Study 3 and Study 4, Paper III, IV)
Encouraging interaction	Gamified a group activity (co-located icebreaking activity) and apply information asymmetry to the game for the activity (Study 5, Paper V)
Enforcing interaction	Transform a typically solitary activity (photo taking with camera phone) into a collaborative activity with interaction asymmetry (Study 6, Paper VI)

Mobile Technology Inviting Interaction

In this thesis, mobile technology invited interaction, both between strangers and acquaintances, by providing information that could potentially develop into a conversation (Study 1, Study 3 and Study 4) and by triggering actions and engaging users into a shared activity (Study 2). Mobile technology inviting interaction had a rather active character in an interaction, i.e., the technology offered information and opportunities that could be potentially interesting to users (and others around them in Study 4) without users having to actively perform any inquires. However, mobile technology inviting interaction was underwhelming in generic contexts, such as a local community (Study 1), a random encounter (Study 2), and on a daily basis (Study 4).

Information provided by mobile technology, at times, was used as a source for conversation by co-located others around the users in Study 4. However, the information was often considered only as “good to know” information, but was not motivating enough to develop any face-to-face interactions. Similar opinions were also reported in Study 1. The study further indicated that information that contains concrete purposes of interaction (e.g., related to sports or hobbies) would have more potential to invite and bring strangers within proximity together than information that is purely about a single person or merely for socializing purposes, like partying.

Study 2 used a proactive character of mobile devices to invite interaction and engage them into a shared activity. Findings from the study show that mobile technology can trigger and invite interaction between strangers. However, participants in the study did not appreciate the active character of mobile technology, and they were concerned that the technology could put them in an awkward situation. Proactively engaging participants into an activity was considered too forceful and users would prefer to control the behavior of the technology.

Mobile Technology Encouraging Interaction

In this research, mobile technology encouraged interaction between strangers in a gamified self-introduction icebreaking activity (Study 5). The information asymmetry concept was employed in the design of the game to encourage interaction. Although the activity was organized and initiated by researchers, mobile technology was responsible for managing the activity and the users’ actions during the activity. The presence of mobile technology in the activity did not isolate users from each other and information asymmetry in the game kept users engaged and also encouraged interaction between them. A variety of interactions between the users was observed, including assisting and teasing each other. Users also developed short conversations during and after the game based on the information learned about each other during the game provided.

Mobile Technology Enforcing Interaction

In this research, mobile technology enforced interaction between acquaintances and between strangers in a photo taking activity, turning a typical solitary activity into a collaborative activity (Study 6). The interaction asymmetry concept was employed in the design of the activity. Each user within a pair had different interaction abilities (viewfinder and trigger). Technology enforcing interaction usually results in some kind of interactions between users. In the study, both collaboration between the users and a user commanding the other are observed. Users' behaviors varied based on their interpretations of the abilities assigned to them. The additional outcome of this design of technology is experience in the activity enhanced with social interaction. For example, users reported being inspired by each other and become understanding, rather than annoyed, when their partners stopped to take a photo.

6.1.2 Design perspectives for Mobile Technology in Co-located Interaction

Mobile technology may be seen as a disruption of social interaction in a co-located situation—distracting attention of mobile device users away from their physical surroundings. On the other hand, mobile technology can encourage social interaction or mobile technology and social interaction, together, can enhance an activity experience. The literature review and the studies in this thesis have shown that mobile devices have the potential to fulfill all the design objectives for enhancing co-located interaction.

The small size of mobile devices and their personal nature are common challenges all researchers and designers have to deal with when designing mobile technology for co-located interaction. Typically, researchers and designers try to *overcome these limitations*. However, that is not the only solution. Being co-located allows researchers and designers to consider face-to-face interaction in the designs and *utilize the limitations* to encourage face-to-face interaction and engender new experiences in an activity. The following further describes and discusses these two design perspectives (overcoming the limitations and utilizing the limitations) based on insights from the studies conducted in this thesis. This includes also reflections with related work and the relationship between the design perspectives and the design objectives.

Overcoming Limitations of Mobile Technology

The small size of mobile devices limits sharing and interaction capabilities. This reduces the availability of information, the control of actions and also the awareness of actions of others, which are important for multiuser interaction and collaboration (Yuill and Rogers, 2012). Furthermore, the small and personal characteristic of mobile devices also decreases the opportunities for shared experiences and serendipitous interactions around an activity, which are relevant for technology inviting interaction.

Many mobile systems designed for co-located activity intend to facilitate interaction. According to the literature, these systems emphasize users having access to the same content. In other words, these systems focus on overcoming the limitations. They overcome the limitations through fluent connectivity (Lim et al., 2014), extended form factors (Winkler et al., 2014) or novel interaction techniques (Lucero et al., 2011).

For mobile technology that intends to invite interaction, the focus is to provoke and promote face-to-face interaction. The design of technology is centered on neither overcoming the limitations, nor utilizing the limitations. Often, mobile devices are considered to be a channel for providing potential opportunities for interaction and do not bother about the limitations. For example, *DigiDress* basically provides information about surrounding people to the users through mobile devices (Persson et al., 2005). However, some consider the limitations as an inspiration for design. Study 3 and Study 4 (*Social Display*) were motivated around the mobile device interface decreasing the surrounding others' awareness about the activity of the mobile device users, hence, reducing social elements and opportunities (e.g., easy observation or joining in). Social display provides awareness information about mobile device users' activities through an extended display, overcoming the lack of activity awareness on mobile devices and thus inviting interaction.

Furthermore, if mobile technology is not just about providing information, but rather engaging users into a shared activity as in Study 2 (*Social Devices*), then mutual understanding about the activity between users is important. The small size of mobile devices can hinder the potential of inviting interaction. Thus, Study 2 employed audio output to draw attention and engage users into a shared activity.

Utilizing Limitations of Mobile Technology

The small size of mobile devices may limit sharing and interaction capabilities. However, being co-located allows mobile device users to overcome this limitation with direct communications between users, e.g., speaking aloud or showing the screen to others (Weilenmann and Larrson, 2001; Church et al., 2012). Reiley et al. (2008) have shown that pairs of users could manage their navigations through a museum using a single mobile device. Furthermore, this limitation naturally engenders interaction and communication in a co-located group activity. However, utilizing limitations is not about leaving the limitations the way they are; rather, it is about designing and balancing between technology overcoming the limitations and letting the social conventions take care of them. For example, users in a Collaborative Camera study (Study 5) had different interaction abilities across multiple devices in photo taking. However, they were provided with synchronized displays during the task to facilitate the activity.

Mobile technology with the intention of encouraging or enforcing interactions often associates some constraints on the users. These constraints are used to motivate or create needs for users to interact or collaborate with each other in an activity. Often, these systems utilize the small size and personal nature of mobile devices to create these constraints. The studies (Study 5 and Study 6) implemented the asymmetry design concept—i.e., different users have different information or interaction abilities—for creating constraints between users. The nature of mobile devices allows the concept to be easily implemented, providing different information or assigning different capabilities for users.

6.1.3 The Role of Mobile Technology in Co-located Interaction

At the beginning of this thesis, four design objectives were introduced based on existing literature. This thesis only focuses on three design objectives (inviting, encouraging and enforcing interaction). While there are many ways to achieve these objectives, five design concepts were produced in this thesis to fulfill these objectives with mobile technology embracing two *roles* (*information provider* and *activity facilitator*) and behaving in two particular ways in a co-located interaction.

In this thesis, four studies (Study 1-4) focused on the objective of *inviting* interaction. The role of mobile technology in Study 1 and Study 4 primarily acted as an *information provider*. The role offered possible topics for conversations and information, aiming to provoke and promote face-to-face interaction. However, this is not the only way to invite interaction through technology; some systems can invite interaction by engaging users into a shared activity. *Social Devices* (Study 2) drew the attention of the users with provocative behavior by the mobile devices. They, then, engaged users into a shared activity engendered by the devices. The system did not provide any particular information that could trigger a conversation. Instead, it drew attention from the users with their active behavior (i.e., *Social Devices* automatically play audio to encourage users to interact with the systems). Then, the system provided interaction spaces for users to interact with each other (i.e., users, together, responded to questions and requests asked by the *Social Devices*). The system partly adopted the role of *activity facilitator* with a function to catch users' attention.

In this research, mobile technology acted as an *activity facilitator*, managing and manipulating users' actions, with an aim to encourage or enforce interaction in an activity. Study 5 (*Who's Next*) gamified an icebreaking activity, and mobile technology was responsible for driving the flow of the activity. Multiple mobile devices were used to assign different roles to the users in an activity and enforce collaboration in Study 6 (Collaborative Camera). Table 5 summarizes the roles of mobile technology in relation to the design objectives and design concepts of this thesis. The following further describes these roles in relation to the studies that were conducted in the thesis and other related work.

Table 5: Summary of relations between design objectives, design concepts, and role of mobile technology

Design Objectives	**Design Concepts**	**Role of Mobile Technology in Co-located Interactions**
Inviting interaction	Engender ticket-to-talk (Study 1, Paper I)	Information provider
	Engender social triangulation (Study 2, Paper II)	Activity facilitator
	Increase activity awareness with additional display (Study 3 and Study 4, Paper III, IV)	Information provider
Encouraging interaction	Gamified a group activity (co-located icebreaking activity) and apply information asymmetry to the game for the activity (Study 5, Paper V)	Activity facilitator
Enforcing interaction	Transform a typically solitary activity (photo taking with camera phone) into a collaborative activity with interaction asymmetry (Study 6, Paper VI)	Activity facilitator

Mobile Technology as Information Provider

In this research, in order to invite interaction, mobile technology provides users (and others around them) with information that could be a source or reason for an interaction. Mobile technology provided information about things happening around users (Study 1) and about mobile user's activity on the device to others in their surroundings (Study 3 and Study 4). Findings from the studies and related work indicate that one possible role of mobile technology in co-located interaction is of an *information provider*.

Internet and searching are two of the most used activities on mobile devices (Brown et al., 2014). Mobile devices, in general, allow their users to access various information. That is, they already act as information providers. Often, they are sources for mobile device users to come up with conversation topics (Brown et al., 2014; Porcheron et al., 2016). While this role just provides information as another ordinary information technology, it has a clear intention to provoke or promote face-to-face interaction. It allows not only mobile device users, but also people surrounding them, to initiate an interaction with each other, based on the information provided by mobile devices. For example, in Study 4 *Social Display* increased activity awareness and allowed the surrounding people to initiate a conversation based on the activity of the mobile device users, instead of only the users raising a topic related to the content he/she is looking at on the device, which is usually how it happens.

Mobile Technology as an Activity Facilitator

Facilitator literally means "one that helps to bring about an outcome (as learning, productivity, or communication) by providing indirect or unobtrusive assistance, guidance, or supervision."[11] In this research, mobile technology acts as an *activity facilitator* by focusing on coordinating and manipulating the users' actions to encourage participation and interaction between users during an activity. *Who's Next* (Study 5) and *Social Devices* (Study 2) provided interaction spaces for shared activities as well as gave instructions or requests that guided and/or motivated the activities. Furthermore, the mobile devices also gave users the perception that the actions or instructions performed by the devices were directed or assigned to the users and that they should respond accordingly (Study 2 and Study 6). In addition, mobile technology can take responsibility for small and repetitive tasks, such as keeping track of time, monitor users, their performances, respond to users' actions, and enforce rules (Study 5).

6.2 Roles and Design Implementations

The previous section introduces two roles that mobile technology embraced in co-located interaction in this research (*information provider* and *activity facilitator*). This section further describes properties and functionalities of the roles. This is followed by implications for designing mobile technology that embraces these roles. The roles and design implications of the roles serve as a basis for *increasing understanding of mobile technology; outline the design spaces; and provide opportunities for the technology in co-located interaction* (RQ2).

6.2.1 Information Provider

Mobile technology, as an information provider has a rather basic functionality, i.e., to provide information. However, there are a few properties that should be taken into consideration when designing technology for this role. These properties include types of content, timing of the information presented, the presentation space and the context of use. Figure 10 summarizes the design properties for designing mobile technology as an information provider. The following subsections further describe each design property and states inside the property. This is followed by discussions about the design implications for mobile technology undertaking this role. These design properties and design implications

[11]http://www.merriam-webster.com/dictionary/facilitator

are drawn from the outcomes of the studies conducted in this research and reflections of other related work.

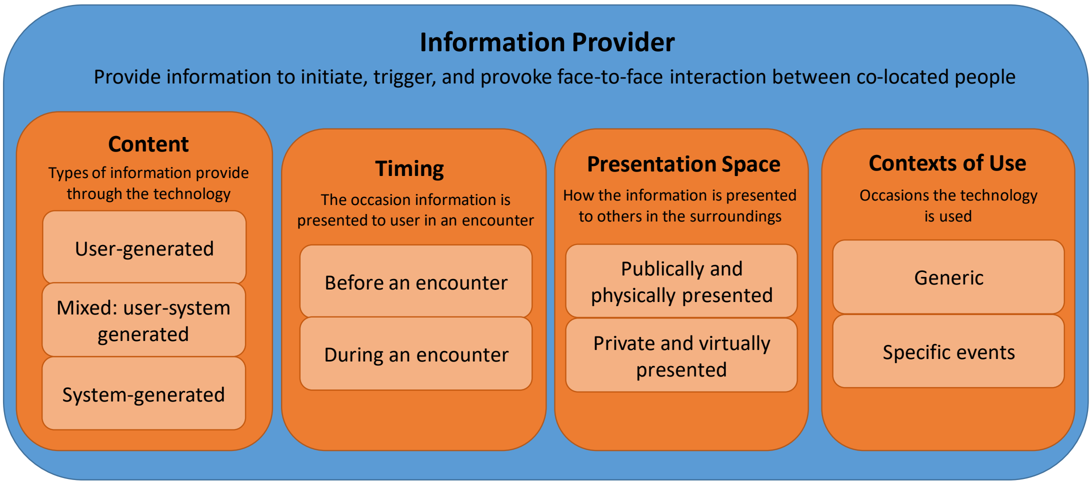

Figure 10: Mobile technology as an Information Provider

Content

Different systems can provide different types of information. There are three types of content that an information provider can provide - user-generated, system-generated and mixed user-system generated content. *Social Display* (Study 4) provides *system-generated* content, based on the users' actions on their mobile devices. This system-generated information is common in awareness applications. The system provides automatic content based on people's actions. *Break-Time Barometer* is another example of a ubiquitous system that provides information about events happening in a workplace, with an aim to motivate people to join the events (Kirkham et al., 2013). Some other systems allow users to generate their own information, for example, *BubbleBadge* (Falk and Björk, 1999), *MugShots* (Kao and Schmandt, 2015), and *Billboard* (Kleinman et al., 2015), to invite and augment face-to-face interaction. Generally, users consider these systems as channels for them to express themselves, tell a story or communicate with others in their surroundings. For example, users of *Billboard* share jokes with each other in their office (Kleinman et al., 2015).

Furthermore, some systems provide information in between user-generated and system-generated, such as user profile-based or social matching systems. Typically, in user profile-based systems, users are guided with certain forms or patterns to share information about themselves. For example, *DigiDress* shows the full profile of other users, including their name, occupation, favorite food/drink, favorite motto, photo or a free text, etc., if users are within close proximity of each other. Similarly, social matching systems usually involve some algorithms or some constraints to be met, before information is provided to the users.

For example, *Social Serendipity* has an algorithm to calculate similarities between users. Only if the similarity score goes above a certain threshold will the users then be notified about each other (Eagle and Pentland, 2004).

Timing

Mobile technology can provide information *before any encounters* and can attempt to bring users together or trigger an interaction, based on the information provided to them. *Social display* (Study 4) and *Billboard* (Kleinman et al., 2015) are examples of technology that attempts to provoke face-to-face interactions between device users and others around them, through the information provided on the backside displays. Alternatively, mobile technology can provide information *during an encounter* to facilitate the encounter after users have met and started to interact with each other. *MugShots* (Kao and Schmandt, 2015) is an example of technology that provides information to facilitate and relieve social awkwardness during an encounter.

Presentation Space

In computer-mediated interaction and communication, sharing content and information between users is limited to the channels that an application provides. Being co-located allows the use of physical space and direct interaction between users to share information. For example, passing around a single mobile device to share a photo on the device within a group. Some systems take advantage of this opportunity and expose information publicly in the physical space to encourage face-to-face, rather than face-to-screen interaction. *Social display* (Study 4) presents the mobile device user's activity as public in the physical space. This allows others in their surroundings to directly glance at the display and know about the mobile user's activity without having to go through another application. Hence, interaction between users or between users and viewers happen naturally and directly in the form of a face-to-face interaction. Furthermore, presenting information on the physical space provides users with a rich awareness about who is looking at their content and can timely react to the situation (Study 4). *Meme Tag* (Borovoy et al., 1998) utilized this glanceable and rich awareness of the information presented on the physical space to create a special occasion by proactively switching name tags of two users to invite interaction between them.

Some systems provide information only in the digital realm because users are in proximity, but not yet co-located, e.g., concepts introduced in Study 1 or *DigiDress* (Persson et al., 2005). *DigiDress* only shows profiles of other nearby users in the application. Presenting information only in the digital realm is easier and makes it possible to control who has access to the information, such as only to those who use the application and not everybody in a certain place. However, users usually lack in knowledge about who is viewing their information. Raento and Oulasvirta (2008) provide a full list of design principles, concerning privacy and self-presentation that designers and researchers should contemplate when designing mobile technology for providing information in the digital realm.

Contexts of Use

In this research, mobile technology acts as an information provider to invite interaction employed in a generic context. The *Social Display* prototype (Study 4) was carried around in the users' daily lives without a specific purposes besides providing additional awareness information to others around them and possibly invite interaction. On the other hand, some systems intend to be used for special purposes or events. *CommonTies* is a matchmaking system, focusing on networking events as the main context of use (Chen and Abouzied, 2016). *CommonTies* is based on a single LED to identify users that are matched with other users. Despite the content these systems provide, *Social Display* only occasionally succeeded in gaining engagement between people who already knew each other. *CommonTies*, on the other hand, reports to bring most of their users to meet face-to-face during the event. The difference between *CommonTies* and *Social Display* are the users' goals. *CommonTies* is used in a context that users are already willing to socialize with each other. Thus, users take advantage of information provided by the system. On the other hand, *Social Display* users and others around them (who view the content on the display) did not have any particular goal to interact with each other. Thus, information provided by *Social Display* was often just good to know.

Design Implications of Mobile Technology as an Information Provider

This section presents design implications that researchers and designers should consider when designing mobile technology as an information provider. These implications are based on insights gained from studies and reviews of existing literature.

> *Design Implication 1: Types and richness of content does not guarantee the effectiveness of mobile technology for inviting interaction.*

The choice of content is highly dependent on the application area that a system is designed for or how it is intended to be used. For example, *Social Display* (Study 4) utilized system-generated content for awareness purposes. However, there is no clear relationship between the type or the richness of the content and the potential of mobile technology in inviting interaction–i.e., providing only a little information does not mean that a system would fail to invite interactions; similarly, providing rich information does not guarantee that a system would succeed. *Social display* (Study 4) and *Billboard* (Kleinman et al., 2015) are two similar systems that aim to invite interaction between device users and surrounding people. *Social display* provides system-generated content, and *Billboard* is based on user-generated content. The systems occasionally invited interaction, but are limited only to acquaintances. On the other hand, *CommonTies* provides system-generated content based on one LED to identify users that are matched with another person (Chen and Abouzied 2016). Despite the minimal content that the system provides, *CommonTies* reports that most of their users looked for each other and met face-to-face.

Information provided by the technology can be used as a source of conversation (Study 4) and can facilitate and/or relieve tension in an encounter (Kao and Schmandt, 2015). However, it requires further exploration to draw the line between richness of content and to what extent it can promote an encounter, as users' opinions vary from one situation to another. *CommonTies* reports that their users were satisfied with minimal information provided through a single LED. Conversely, people in the surrounding of *Social Display* would prefer to have more information on the display (Study 4).

Design Implication 2: A provocative character of mobile technology helps trigger an interaction.

Although *Social Display* (Study 4) can occasionally invite interaction between acquaintances, information provided by *Social display* was often considered as good to know information. It is vital that a system should not only provide a source of information for conversation, but also have a provocative behavior that can draw attention and trigger an interaction. *Meme Tag* is an example of a system that successfully triggers an interaction and provides information to users at the same time (Borovoy et al., 1998). In addition to personal information presented on the tags, *Meme Tags* has a proactive character that actively pairs users in proximity, which helps trigger interactions between them.

Design Implication 3: Information publically presented in a physical space should be safe to be viewed by everybody, including strangers.

Exposing information publicly in physical space underlines the relationship between information and users, and it directly projects the users' identities to others who can see the content, including strangers. As a result, users are conscious and careful about the content being presented. Users of *Social Display* reported that they are more careful about their activities on mobile devices and the appropriateness to use the devices, especially concerning surrounding activities and people (Study 4). Often, *Social Display* users reported suspending the use of mobile devices in situations that were not appropriate. While this can break the habit of overusing mobile devices, the role of mobile technology as an information provider that invites interaction is not really imposed. Similarly, the study of *Billboard* reported that the users usually just limited their interactions on the application to jokes, banter or something from the Internet. Nothing about work-related or serious subjects were mentioned when being employed in public places. Users preferred to present different information, depending upon the local context, instead of only providing information about themselves (Study 3, Study 4 and (Kleinman et al., 2015)). For example, *Social Display* users prefer a customizing option for content on the display to include other information like campaigns they are supporting, challenges and goals they are trying to accomplish, or even some advertisements (Study 4).

Design Implication 4: Target a specific context where users are motivated to interact with each other.

Being co-located or having a similar daily routine does not mean that people would like to interact with each other. Rather, people tend to avoid interacting, especially with strangers that they usually encounter on a daily basis (Goffman, 1963). Furthermore, people typically need a reason to start interacting with strangers (Sacks, 1992). For technology embracing the information provider role, the success of a system to trigger interaction highly depends on the users' motivations. While providing interesting information may be enough to invite interaction between acquaintances (Study 4), it is not enough to motivate and invite interaction between strangers (Study 1, Study 4 and (Kleinman et al., 2015)). Users take advantage of the information only if it can be used to fulfill some of their own goals while interacting with others (Study 1) rather than the other way around. The contexts of use help frame the users' intentions and goals (Mayer et al., 2015). Instead of focusing on a generic context, where a system also has to build the users' motivations to interact with each other, mobile technology is more appreciated for facilitating an encounter and successfully inviting interactions in a context that users are already socially active. *CommonTies* has shown that as minimal as a single LED can provide enough information to invite interaction between strangers in a situation when the users are motivated (Chen and Abouzied, 2016). Mayer et al. (2015) also reported similar findings and further listed different conditions in which people would like to meet with others.

6.2.2 Activity Facilitator

Technology has been a facilitator in digital games for some time (Salen and Zimmerman, 2004). This research shows that this role of technology is not limited to only activity in a digital realm, but also influences and motivates users to take actions in the physical realm.

The main actions of the technology as a facilitator are assigning tasks/roles and enforcing rules in an activity (Figure 11). In this research, these actions are driven by the asymmetry property in the design of the applications. The following further describes these actions and design implications for mobile technology undertaking this role. The design implications are drawn from the outcomes of the studies conducted in this research and reflections from other related work.

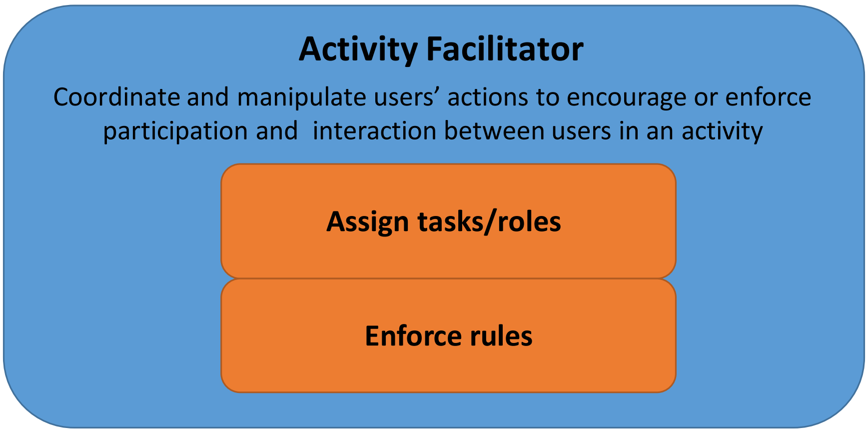

Figure 11: Mobile technology as an activity facilitator

Assigning Tasks/Roles

Social Devices in Study 2 has shown that mobile technology offers users the perception that instructions given by the devices are directed to the users, and they should respond accordingly even though they do not personally own the devices. *Who's Next* (Study 5) and Collaborative Camera (Study 6) extended this idea further, adopting the concept of *asymmetry* in the design of the systems. *Asymmetry* is dissimilarity in multiple forms (e.g., fidelity, engagement, participation or benefit) (Voida et al., 2008). It is also a design concept commonly used in game designing to encourage interaction between players, which can either be for collaboration or competition (Björk and Holopainen, 2004; Zagal, 2006). Furthermore, asymmetry is considered an approach that implements *positive interdependence*, a condition within a group that leads to collaboration between group members (Johnson and Johnson, 1994). Asymmetry in mobile devices allows joint rewards, divided resources and divided role dependency, which are common methods of creating positive interdependence to be easily implemented.

Mobile technology in these two studies (Study 5 and Study 6) was used to assign different tasks and roles based on information and abilities of each device. It also helps in sustaining the roles and tasks that are assigned to users to be consistent throughout the activities. These roles and tasks act as a protocol that guides the users how they are expected to enact and allows the use of technology to manipulate and encourage the users' actions and participation in the activity. This research implemented two forms of asymmetry, *information asymmetry* (Study 5) and *interaction asymmetry* (Study 6). Although they lead to interaction and collaboration between users, they provided different mechanisms that influence users' behavior and interaction in a co-located social activity.

Enforcing rules

In this research, mobile technology enforced rules, handled the users' actions, and responded to them. For example, giving feedback for a right or wrong answer (Study 5), enforcing a rule that users cannot move on in the activity unless they answer a question correctly (Study 5) or sustaining assigned roles for each user throughout the activity (Study 6). Mobile technology shifts the role of human facilitators to a supervising perspective and creates more distance from participants, which allows participants to focus more on their activities and interaction between them, rather than creating meta-interaction with a human-facilitator, e.g., giving feedback for an answer (Study 5). Furthermore, this allows breaking users or participants into smaller groups, which is considered better for encouraging interaction within the group (Dennick and Exley, 2004). Sometimes, technology does not act as a main facilitator, but assists human facilitators in facilitating activities. For example, *UniPad* as a classroom-based simulation system does not totally exclude the teacher from the activity. The teacher is still there to facilitate the classroom and support the students, but the system allows the teacher to easily control the pace and time of the exercise in the class, together as a whole.

Design Implications of Mobile Technology as an Activity Facilitator

This section presents design implications that researchers and designers should consider when designing mobile technology as an activity facilitator. These implications emphasize employing the asymmetry concept on mobile technology. They are based on insights gained from studies and reviews of existing literature.

Design Implication 1: Technology should focus on facilitating the activity procedure, but not dominate the activity.

Facilitators should facilitate an activity, but should not dominate it or be the center of attention (Bens, 2012). In terms of technology embracing the role, it should provide a procedure that supports an activity, i.e., mobile technology that gives instructions, requests and asks questions to the users as they proceed through the activity. However, *social devices* (Study 2) overdid the role as activity facilitators. They provided users with instructions and requests to invite and encourage interaction between them. For example, participants were asked to introduce themselves to each other, which they did. However, the devices were dominating the activity, and most participants did not do anything beyond the instructions given by the devices. On the contrary, in Study 5 the design of mobile technology manipulated the procedure of the activity (e.g., asking questions, managing turns, tracking time and the users' actions), instead of actually telling users what they should do. A variety of interaction patterns between users were observed across the sessions, and some were richer than others. However, it allows users to freely decide how socially active they would like to be in an activity (unlike users from *social devices,* who reported the feeling of being forced to interact with each other).

Design Implication 2: A design should provide a clear interaction goal in the activity.

Who's Next (Study 5) implemented the *information asymmetry* concept, where different users have different information. Users can freely handle the information they have in the activity, depending on the goal of the users. *Who's Next* has a clear system goal in getting users to get to know each other and engage them into a shared activity. However, the game does not state a clear goal for users; they should be either competing against each other or working together in a group as a whole. Thus, a variety of interaction patterns was observed, both helping and bluffing. *Spaceteam*[12] is multiplayer game where players also have different sets of information. The game clearly positions itself as a cooperative game, and the goal for players is to win the game together. Accordingly, players of the game collaboratively handle the information to win the game. To summarize, for *information asymmetry*, the overall goal of the activity guides the interaction pattern between users, whether or not they collaborate with others.

Design Implication 3: The design should balance the significance of the interaction abilities between users.

The Collaborative Camera (Study 6) implemented *interaction asymmetry* in a pair-photo taking activity. Different interaction abilities were assigned through the users' possession of mobile devices. While users collaborated with each other rather well, varieties of interaction patterns were also observed. These are related to the users' interpretation of their abilities. If users perceive their assigned interaction abilities to be more significant and contribute to the activity, it increases their level of engagement and participation in the activity and vice versa (Study 6). Thus, to successfully employ *interaction asymmetry,* the interaction abilities should be equally important to create a sense of significance in the activity.

[12] http://www.sleepingbeastgames.com/spaceteam/

Design Implication 4: Mobile technology should guide users where they should focus their attention during the activity, balancing attention between technology and one's surroundings.

In this research, mobile technology provided space for shared activities. The small size of mobile devices limits the sharing and interaction capabilities. Thus, a space for a shared activity is located across multiple devices - one device per user (Study 2, Study 5 and Study 6). This is to increase the availability of information, control of actions and the awareness of others' action, which are important for interaction and collaboration (Yuill and Rogers, 2012). When technology is involved in an activity, it draws attention from the users. The presence of mobile technology is found to negatively influence the users' interaction quality in situations where users are also expected to interact with other users and the surrounding environment (Lanir et al., 2011; Przybylski and Weinstein, 2012). In co-located interaction, interaction space spreads in both digital and physical realms. This requires users to split their attention, between interacting with technology and interacting with other co-located users. Designers and researchers should be aware of this matter and consider balancing their attention between these two interaction spaces. Otherwise, it can result in users just paying attention to their own devices and actions and ignoring others around them.

While it is impossible to absolutely control where users focus their attention, technology can be designed so that it guides users to focus their attention in a particular direction. For example, *Who's Next* (Study 5) adopted the turn-based interaction, where only one user can interact with the technology at a time, and others just wait for their turns. This prevented the situation where every user would only pay attention to their devices. However, this raises another concern regarding users losing their engagement in the activity while waiting for their turns. *Who's Next* keeps users engaged in the activity by allowing active users to take advantage of interacting with non-active users. This encouraged active users to not only pay attention to his/her action on the digital realm, but also consider face-to-face interaction with others in the physical realm. It also allowed non-active users to influence active users' actions and decisions, which helped in maintaining their engagements with the activity. Alternatively, *UniPad* adopted a hard way to direct the users' attention. The facilitator (teacher) locks the tablets whenever s/he would like to move the focus of the users (students) back from their small group work to the classroom as a whole (Kreitmayer et al., 2013).

7. Discussion and Conclusion

This chapter summarizes and discusses research methods, research setup and how research goals and research questions are addressed in this thesis.

7.1 Methodological Discussion

One of the research questions of this thesis is related to the user experience and the interaction patterns between users, which are engendered by involving mobile technology into co-located interaction (RQ1). The main study contexts of this research are when users are co-located, where direct interactions between users are possible. This means that not all interactions between users are mediated by technology. Thus, logging the interaction activity could not provide any results. To address the question, it required researchers to be able to observe users while using the technology and interacting with others. Most of the studies conducted in this thesis were organized, and the contexts of use were simulated.

This thesis included four studies that involved prototypes (Study 2, Study 4, Study 5 and Study 6). However, Study 4 was the only study in which participants actually used the prototype in their daily life. The other three studies were arranged, and the contexts in which the prototypes were intended to be used were simulated. The main drawback of the arranged studies is that participants lacked background context or motivation in the target activities, which could influence the participants' interaction patterns. Study 6 simulated photo taking activities, using different photo taking methods. Participants were given topics for photo taking and a limited amount of time to take the photos. Even though a reason for doing the activity was provided, the simulation lacked personal motivation, which is common for the activity, e.g., for personal memories or to show family and friends later. Thus, the activity started out with quite an artificial atmosphere. Although the participants were eventually immersed in the activity and interesting interaction patterns were observed, the limited time and the absence of personal motivations in the beginning might restrict some other interesting findings.

Similarly, *Who's Next*, a mobile icebreaking activity game, aims to facilitate strangers in getting to know each other (Study 5). Generally, icebreaking activities are usually held at the beginning of an event (e.g., a classroom, a summer camp or a seminar), where the activities are followed by other events or participants later spend long periods together. However, in the study, participants were invited just for the study, which lasted for a duration of approximately one and a half hours. The set-up of the study lacked reasons why participants would want to get to know each other or collaborate in the activity. Although interesting interaction patterns were observed in the study, it is likely that in a real setting, interactions between participants could have been richer and more extensive. Similar concerns are associated with Study 2 for *Social Devices* when attempting to invite interaction between strangers.

Study 4 (*Social Display*) required participants to install the prototype on their mobile devices and use it in their daily life. The duration of the study was 10-12 days. Constant observation was not possible; hence, the results were based on self-observation and the participants' answers in daily questionnaires and interview discussions. Some interesting incidents might have been missed or forgotten. Furthermore, the study involved two roles of the users - information providers and viewers. Participants with the prototype undertook the role of information provider and others whom the participants encountered were viewers. Unfortunately, the access to the viewers was limited. Findings regarding the viewers' experiences were primarily based on the participants' reports of their discussion with some of the viewers that they had encountered. This restricted the possibility to ask further questions for additional clarifications. The results of the study could have been more complete if there was better access to the viewers the participants came across. In addition, the study produces findings from early adopter perspectives, when participants were the only people within their social circle that had the prototype. While the participants did not report being ashamed of having the prototype, *Billboard* users mentioned that they would be more likely to use the system, if others are also using it (Kleinman et al., 2015). This shows that the number of users affects the opinions about the system—more users may bring more opportunities and positive opinions.

7.2 Revisiting Research Questions and Contributions

This thesis presents a model for designing mobile technology for co-located interaction. The model is an outcome of an analysis of empirical findings from user studies and an extensive review of related work. It consists of three design aspects - *design objectives*, *design perspectives* and *roles*. Design objectives extend the design approaches of Benford et al.(2000) for collaboration on a shared interface. This research redefines the approach as objectives for designing the mobile technology that enhances co-located interaction. Furthermore, the focus is beyond the shared interface and collaboration and considers separate interfaces and other forms of social interactions, like encounters or competitions. Design perspectives and roles are novel concepts synthesized from empirical findings of the user studies, reflections with related work, as well as insights and understanding gained throughout the research process. The model can provide guidance to researchers and designers in how to design mobile technology for co-located interaction.

The other research questions of this thesis are concerned with *the outcomes from introducing mobile technology in co-located interaction, including emerged interaction patterns and the user experience (RQ1)*. To address the question, this research introduced five distinct design concepts and conducted user studies to learn about their consequences on co-located interaction between users. Empirical findings from user studies have shown that mobile technology can enhance co-located interaction, fulfilling the objectives of inviting, encouraging and enforcing interaction. Mobile technology inviting interaction generally has an active behavior, offering opportunities and information that might be interesting to users. The technology is appreciated and is successful in inviting interaction in situations where users are socially active or aiming to socialize. Otherwise, the technology is often considered to provide only good to know information. Furthermore, technology with very active behavior is also not preferred, as it could potentially lead to an awkward situation.

Mobile technology can be used in co-located group activities to encourage interactions between group members. This research utilized the small size and personal nature of mobile technology to create an incentivized situation in a group activity. The situation motivated and drove users to interact with each other, including helping, supporting and teasing. In addition, the small size and personal nature of mobile technology could be used to enforce interaction in a group activity. Users had to interact with each other in one way or another, including both collaboration and one person dominating the other. Interaction between users added another layer of experience to the activity, which was appreciated by most of the users.

This thesis identified two roles of mobile technology - *information provider* and *activity facilitator*. These roles of mobile technology and empirical findings from user studies offered understandings for how the technology can be designed to enact in a co-located situation. This addresses the overall research goal of this thesis for providing a better understanding of the technology in this domain. In addition, this thesis also delivers design implications for mobile technology embracing the roles. For mobile technology acting as an information provider, there is only a simple functionality for the role, which is to provide information. The design implications concern design properties related to types of content, timing the information provided, how information is presented, and the contexts of use. For technology as an *activity facilitator* role, this research identified functionalities of the technology embracing the role, including assigning tasks and enforcing rules. The design implications are about how much technology should be involved in an activity and managing the users' attentions between interacting with technology and with the surroundings. These implications address the research question in *opportunities and considerations for designing mobile technology to enhance co-located interaction (RQ2)*.

7.3 Future Work

This thesis presents a model for designing mobile technology for co-located interaction. The model includes design objectives, design perspectives, and roles and design implications. However, neither the model, roles, design implications, nor design perspectives are absolute. The roles and design implications are synthesized from empirical findings of studies conducted in this thesis with reflections from existing literature. The thesis presented two roles (information provider and activity facilitator) of mobile technology. However, the roles are rather generic, support multiple application areas and have multiple functionalities. Further studies are needed to break down these roles and explore other possible roles of mobile technology in co-located interaction. Furthermore, majority of concepts introduced and studies conducted in this thesis attempt to invite interaction (4 studies) and only two studies explore the technology encouraging and enforcing interaction. Further studies could explore these latter two design objectives further, which might lead to other roles and design implications of the technology.

The model presented in this thesis is based on the design process of this research. The design process started by considering the possible design objectives that mobile technology could fulfill, followed by design perspectives that support the objectives, and possible roles the technology could have. These design aspects could be considered in a different order in the design process; however, a validation of the model is needed.

Although studies conducted in this research focus on mobile devices in form of smartphones, most of the findings reflected in the related work, undertake multiple forms of mobile devices. The outcomes of this thesis could potentially be applied to a variety forms of mobile technology intended to be used in co-located interaction. Further validations of the outcomes are also needed for other forms of mobile devices.

To conclude, technology and social interaction have quite a complex relationship. This thesis mainly focuses on mobile technology enhancing co-located social interaction. The latest study (Study 6) and some related work have shed light on the potential of mobile technology together with social interaction can enhancing performance and experience in an activity. Although, this combination is not new, collaborative learning domain has considered this for a while. The questions are - how can this combination be extended in other domains and what are the design implications and considerations, when designing mobile technology for these domains.

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Original Publications

Publication I

Jarusriboonchai, P., Olsson, T., Ojala, J. and Väänänen, K. Opportunities and Challenges of Mobile Applications as “Tickets-to-Talk”: A Scenario-Based User Study. In Proceedings of the 13th International Conference on Mobile and Ubiquitous Multimedia (MUM’14). ACM Press (2014), 89-97.

Publication II

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Publication III

Jarusriboonchai, P., Olsson, T. and Väänänen-Vainio-Mattila, K. Social Displays on Mobile Devices: Increasing Collocated People's Awareness of the User's Activities. In Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI'15). ACM Press (2015), 254-263.

Publication IV

Jarusriboonchai, P., Malapaschas, A., Olsson, T. and Väänänen, K. Increasing Collocated People's Awareness of the Mobile User's Activities: a Field Trial of Social Displays. In Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing (CSCW'16). ACM Press (2016), 1691-1702.

Publication V

Jarusriboonchai, P., Malapaschas, A., and Olsson, T. Design and Evaluation of a Multi-Player Mobile Game for Icebreaking Activity. In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI’16). ACM Press (2016), 4366-4377.

Publication VI

Jarusriboonchai, P., Olsson, T., Lundgren, S., and Väänänen, K. Let's Take Photos Together: Exploring Asymmetrical Interaction Abilities on Mobile Camera Phones. In Proceedings of the 18th International Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI'16). ACM Press (2016)

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