Designing Solutions to Mediate Co-located Smartphone Usage

by

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

MASTER OF SCIENCE

in

THE COLLEGE OF GRADUATE STUDIES

(Computer Science)

THE UNIVERSITY OF BRITISH COLUMBIA

(Okanagan)

December 2022

The following individuals certify that they have read, and recommend to the College of Graduate Studies for acceptance, a thesis/dissertation entitled:

Designing Solutions to Mediate Co-located Smartphone Usage

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Abstract

There is a growing concern that smartphone usage in front of family or friends can be bothersome and even deteriorate relationships. In my thesis, I design solutions to improve co-located communication between partners. I start my exploration with a survey examining co-located smartphone usage among partners. Results show that people often feel frustrated when their partner uses a smartphone in front of them and are not fully aware of their partner's smartphone activities when co-located. This motivated me to design a smartphone application, CoAware, for sharing smartphone activity-related information between partners. Results from a user study with couples show that CoAware has the potential to improve smartphone activity awareness among co-located partners. However, CoAware doesn't fully grasp the communication facilitation aspect desired. Thus, I further explore ways to strengthen conversation between co-located couples by introducing a smartphone agent which is designed to interact with humans - like a human. With a user study, I investigate the effects of agent mediation on communication dynamics around co-located smartphone usage in couples. Results reveal that the agent helps motivate users to reduce smartphone usage and is beneficial in promoting co-located interactions.

Lay Summary

There is a growing concern that people overuse smartphones even when they are co-located with family members (e.g., partners), which sometimes leads to anger and frustration. In my thesis, I design smartphone-based solutions to improve co-located communication between partners. More specifically, I design two smartphone applications enabling couples to be aware of their partners co-located smartphone usage and helping them to improve their communication dynamics with a smartphone agent. Results from user studies show that my solutions assist couples in being aware of their partners co-located smartphone usage and improve their communication dynamics.

Preface

This thesis is the original, unpublished work by the author, Karanmeet. This study was granted approval by the University of British Columbia Behavioural Research Ethics Board- Certificate Number: H19-01032-A004.

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Acknowledgements

I would like to thank my supervisor Dr. Mohammad Khalad Hasan. Without him, my time at the university and doing research wouldn't be as enjoyable. He was always available for meetings and would always provide great feedback for me to build on. He also connected me with other professors and provided me with new opportunities to endure. His work ethic is unmatched, even if I had questions to ask him at 1:00 AM. My thesis wouldn't be half the product it is without his support along the way.

I would like to acknowledge helpful suggestions from my committee members: Dr. Shan Du, and Dr. Apurva Narayan.

I owe a huge gratitude to my loving family. Their love and support throughout the years has provided me with the motivation to complete my thesis.

Dedication

I dedicate my thesis to my loving parents, Jasvinder and Baljinder Khatra. I want to thank them for supporting me my whole life in whatever endeavour I take on.

Chapter 1

Introduction

Smartphones continue playing a pivotal role in our daily communications with family and friends [8, 65]. Smartphones not only enable seamless communication over long distances, but also allow access to information anywhere, anytime. However, there is growing evidence that people may overuse smartphones, both when alone and in the presence of others, i.e., in a co-located situation [4, 45]. Moreover, smartphones are designed as private and personal devices: the activities that take place on the screen can, when desired, easily remain completely unknown to co-located persons. Not being aware of a co-located person's on-screen activities can cause frustration and even anxiety [68, 75].

A significant amount of work has explored smartphone overuse and its consequences [4, 45, 91]. Much less attention has been devoted to designing solutions for co-located activity awareness which could mitigate the frustration associated with smartphone overuse and improve interpersonal communication. A few recent studies have attempted to increase smartphone activity awareness by helping people to be more aware of co-located people's smartphone activities, providing a rich shared experience, and even motivating people to initiate interaction with nearby persons [43, 68]. These studies suggested different strategies to raise awareness, such as using 'talk-aloud' to pass on what one is doing on the device [68] or to attach a second display to the back of the phone to show on-screen activities to co-located individuals [43]. Though these solutions have the potential to increase smartphone activity awareness, I want to take this a step further by not only reducing this smartphone usage but also further influence the communication dynamics by making partners more aware of what each other are doing on their smartphone.

Social relationships can greatly shape the degree and nature of people's information sharing with other co-located individuals [14, 25]. For example, the information sharing patterns of people with their partner, parents, and children may be very different, and may even vary largely depend on the age of the individuals or the length of their relationship [7, 34]. To narrow down the focus, I concentrate on an in-depth investigation of various aspects of

smartphone use by co-located partners who are married or in a common-law relationship, or in any other (romantic) relationship. I focus on such relationships because partners are often co-located for a substantial portion of each day and their mutual understanding is important for a healthy home environment [17, 31, 66, 94]. Couple relationships are already very nuanced and complex and include many aspects, e.g., closeness, connectedness, interpersonal trust, and perceptions of empathy. This makes them even challenging to study on their own as a focal relationship [14, 31, 64].

In my thesis, I aim to design solutions to improve co-located communication between partners. Thus, this thesis is split into 2 different phases, with 3 studies taking place between these 2 phases. The first phase focuses on designing and evaluating an application (i.e., app) focusing on increasing smartphone activity awareness among co-located partners. The second phase revolves around designing another agent-based app that plays a role in communication facilitation between partners.

Phase 1 begins by conducting a crowd-sourced study (Study 1) aiming to explore the following research objectives: 1) understand people's smartphone habits when being co-located with their partner, 2) gain insight into the concerns that people have about their partner's smartphone usage, 3) understand the rules and privacy issues partners have regarding their co-located smartphone usage, and 4) explore the strategies that people take to become aware of their partner's smartphone on-screen activities. Study results show that people often use smartphones while co-located with the partner, which sometimes leads to anger and frustration. I also found that people often need to respond to their partner's queries about their smartphone activities. Most people share information truthfully, although the details of the shared information vary widely between apps. Furthermore, many people feel that they are not fully aware of their partner's smartphone activities when co-located. This lack of awareness can lead to unpleasant situations. Some strategies such as 'talk-aloud' are being used to be aware of others' smartphone activities, yet there remains a lack of expressive tools to support smartphone activity awareness.

Study 2 of Phase 1 is guided by the findings from Study 1. I explored ways to increase smartphone activity awareness among co-located partners. My goal was to investigate smartphone-based solutions to help partners become aware of each other's smartphone activities and to help them improve their interpersonal communication. I developed a smartphone app, CoAware, that enables users to create co-located smartphone usage awareness by sharing the names, categories, or screens of apps being used by one's partner. Additionally, CoAware enables partners with ways to send notifi-

cations to each other such that they might motivate the partner to reduce co-located smartphone usage. I continued with an in-lab study with couples who explored and provided feedback on the features offered by CoAware. The results revealed that high-level information, such as sharing app names and sending notifications, is useful to provide co-located smartphone usage awareness; however, low-level information about phone usage (e.g., screen sharing) and allowing co-located partners to control a different person's phone were seen to be less necessary and sometimes overbearing. I also found that awareness of a partner's smartphone activities was not desired by all participants. Some participants were satisfied with the level of information they knew about, and some were fine relying on social protocols with their partner to remedy challenging situations.

Phase 2 began with interpreting the results of Phase 1. I found that the features that were to intrusive (ex: screen share, and controlling another person's phone) needed to be removed. In addition, I found that the app didn't fully grasp the communication facilitation that I wanted to see between couples, thus I needed to design a new solution to tackle this problem. The solution to these problems I decided on, was just allowing app name to be shared between couples and also adding in another app that I refer to as the agent-based app which is based around a smartphone agent. Smartphone agents, which are designed to interact with humans - like a human, have been shown to be useful in many smartphone usage contexts. For instance, prior research explored the use of agent-based smartphone applications (i.e., app) for health education and counselling [49], for promoting activities among users with traumatic brain injury [80], to deliver advice regarding medical conditions [9] or for diabetes self-management education [49]. They showed that users became more efficient using agent-based systems [56], had positive perceptions [76] and overall high satisfaction of the agent-based systems [35, 40, 83]. However, I am unaware of prior work leveraging smartphone-based agent systems to facilitate communication between co-located individuals.

For Phase 2, I explore the effect of using a smartphone agent system in influencing communication among co-located people. More specifically, I investigated how a smartphone agent would affect co-located couples behavioural changes, relationships and communication dynamics. Hence, I designed two smartphone apps: (a) an agent-based app that exchanges smartphone usage activities (e.g., app name, app usage duration) among couples while mimicking a virtual agent presenting the information to them. The agent was represented with a name, Anna, an avatar, allowing her to leverage voice modality to send messages and notifications to partners via

audio, and (b) a text-based app where a person can access and exchange the same features manually.

I conducted a between-subject user study (Study 3 of Phase 2) with 12 couples to investigate the effect of the smartphone agent and text-based apps while asking them to use the apps for seven days. I collected their feedback with an exit semi-structured interview where results showed that both the text- and agent-based apps helped couples reduce co-located smartphone usage, access information about what each other was doing, and initiate conversations. However, with the agent-version of the app, couples got the sense of a social entity intervening with them. In addition, the app helped them to stay on track and focus on communication with each other, thus providing valuable mediating support in couples' communication and relationship dynamics.

The chapters of this thesis are structured as follows. First, chapter 2 begins with sharing work related to sharing information between electronic devices, smartphone overuse and effects on individuals and co-located peoples, and current approaches to reduce smartphone usage. Chapter 2 also consists of visiting areas of work related to current approaches to interacting with smartphone agents, mediating and intervention techniques via smartphone agents and effects of social entities on individuals. Chapter 3 begins with Study 1 of Phase 1 providing the goals, procedure and results. Chapter 4 then uses the results of the first study to discuss the app design, which in Chapter 5 brings up Study 2 of Phase 1. Moreover, Chapter 6 begins with interpreting the results of Study 2 of Phase 1 and presents an agent-based app. Chapter 7 discusses Study 3 of Phase 2, including the goals, procedure and results. Chapter 8 discusses the recommendations to design similar strategies that aim at improving interpersonal communication . Chapter 9 includes the limitations of the work and future work. Finally, chapter 10 provides a conclusion.

My thesis makes the following contributions:

- design and implementation of a smartphone app that tracks couples individual and co-located smartphone usage
- design and implementation of a smartphone agent that simulates a human role in facilitating conversation between individuals
- exploration of notifications and a smartphone agent as a way to reduce co-located smartphone usage
- design guidelines for future research at developing co-located interpersonal interaction

Chapter 2

Related Work

I divided my reviewed research work for designing my first text-based app (CoAware) and then my second agent-based app into four major sections namely, Sharing Information between Devices, Smartphone Overuse and Effects on Individuals and Groups, Current Approaches to Reduce Smartphone Interaction, and Smartphone Agents and Effects.

2.1 Sharing Information between Devices

2.1.1 Information Sharing through Digital Devices

Sharing digital devices and accounts are common practices amongst household members, yet this topic has received less attention from an awareness perspective. Instead, the topic has mostly been motivated by the pros and cons associated with device sharing. Sharing devices can be viewed as an all-or-nothing approach for sharing information [44, 61], which gives rise to privacy and security issues [7, 42]. Studies also showed that device sharing concerns depend on the user's relation to the other user as well as the types of data being shared, which suggests the need for better privacy and security models for device sharing [27, 29, 44]. The intricate ways that couples communicate [14] and their need to have a nearly continuous connection have gained deep attention in the literature [31, 66, 94]. This motivated context sharing among people in close relations. Prior research [11, 24, 25, 50] showed how contextual information sharing (heart rate, distance from home, etc.) can be leveraged to make partners aware of each other's context and activities. Both Buschek et al. [11] and Griggio et al. [25] observed that context-awareness improves the sense of connectedness and pointed out interpretability and privacy concerns that may arise due to inferred additional information from the given context. While context sharing helps people in close relationships to be aware of each other's activities, smartphone addiction and overuse of other digital tools may create an awareness barrier even when people are present in the same context.

2.1.2 Usage-Aware Co-Located Smartphones

Though there has been substantial work on different sensing solutions that allow users to track the state of the device [32, 88], very little is known about how to detect two co-located smartphones and how to share information between them. Prior research showed that on-device sensors (e.g., tilt) could be used to make a smartphone context-aware of its state (e.g., orientation) [32], and usage context (e.g., resting on a table) [88]. Beyond sensing a device state or context, researchers explored external sensing solutions to enable smartphones to track surrounding activities and environments [12, 26, 28, 53] and their social acceptance [2], but in limited contexts. To date due to the lack of advances in sensing solutions, such an approach has received little attention in the context of using the space for co-located collaborative interactions for promoting interpersonal engagement.

2.2 Smartphone Usage and Effects on Individuals and Groups

2.2.1 Smartphone Over Usage and Effects on Individuals

Smartphone overuse and smartphone addiction are active areas of research that examine people's smartphone usage behavior. Over the past couple of years there has been an increase in smartphone usage [87, 90]. Researchers have investigated ways of detecting smartphone addiction based on users' smartphone usage behavior. For example, a recent study [65] identifies lifestyle and social media related apps to be associated with smartphone addiction. Researchers have explored and designed solutions to reduce smartphone usage. These include tracking users' smartphone usage and providing them with summarized information to motivate them to limit their smartphone usage [82], designing solutions to allow users to use smartphones for a time period throughout a day [33], and locking the smartphone into a daily use time limit [48]. All three studies showed signs of limiting user's smartphone usage. Researchers showed that reducing smartphone usage is critical as over usage can lead to health effects such as depression, anxiety and a lack of sleep quality [16, 36, 37]. Lee et al. [55] conducted a study using questionnaires on 370 middle school students to analyze the effects of smartphone use patterns on smartphone addiction. Results suggested that smartphone overuse led to a lack of control, withdrawal, mood modification, and loss of interest. Not only can smartphone overuse affect an individual's health but also their work/academic productivity. Duke et al.

[18] used a questionnaire to investigate whether there was any correlation between smartphone addiction, interruptions due to smartphones, and productivity during working. Results showed that smartphone overuse led to a decrease in productivity at the workplace and at home. Samaha et al. [86] conducted a study involving an online questionnaire and 300 university students, aiming to explore what effects smartphone addiction had on stress levels and academic performance. Results showed that smartphone addiction was positively related to stress as well as negatively effected academic performance.

2.2.2 Co-Located Smartphone Usage and Effects on Groups

In addition to overuse in individual smartphone usage, research has also shown smartphone overuse to be an increasing aspect in co-located environments [4, 45]. Kawsat et al. [45] investigated smartphone overuse by logging internet usage from 86 Belgium households and revealed that the overuse was typically prominent in rooms such as kitchens and living rooms. The rising smartphone usage has led to individuals having difficulties separating their smartphone life from their personal life [13, 85]. Additionally, smartphone over-usage has shown to lead to a decrease in work productivity in groups, cause strains in relationships, and even escalate to violence [18, 46]. Further, prior studies have looked into how smartphone overuse by parents, can effect their children. Adair et al. [91] held interviews where they revealed that children often noticed when their parent using their smartphones and resulted in negatives to the children's cognitive and social development. Radesky et al. [81] conducted a study which reported on how parents would use their phones around children at lunchtime. They showed that the usage resulted in the children misbehaving as they would notice their parents on their phones and have minimal interaction with the children. On the relationship aspect, Proulx et al. [79] reported that excessive smartphone overuse can lead to marital disputes and thus lead to stress and depression. Oduor et al. [69] investigated the positives and negatives of co-located mobile device usage in a one-to-one space and wanted to understand how smartphone usage in homes shape the household dynamics. They showed that often times users using phones around family members for non-urgent activities can trigger frustrations among them. Thus, solutions need to be developed to attempt to reduce smartphone overuse in co-located scenarios and encourage more face-to-face interaction.

2.3 Current Approaches to Reduce Smartphone Interaction

Prior research explored ways to reduce smartphone usage and encourage in person communication with others. The two main areas researched include: co-located sharing strategies, where smartphone activities and updates are shared amongst co-located individuals; and notification-based strategies, where smartphone notifications are more intelligently put through between smartphones.

2.3.1 Co-located Sharing Strategies

Researchers explored strategies to share what co-located individuals are doing on their smartphone and find ways to reduce their smartphone usage. Seeburger et al [89] designed an app, Capital Music, that allows users to share real-time song choices with other co-located individuals. The app provides insight into how users feel sharing non-privacy sensitive information such as music selections with one another. Capital Music also attempts to break users out of the "*cocoon*" effect, which takes place when users are confined to only themselves and have no realization of activities around them. Other researchers have investigated ways to mitigate or limit smartphone distractions in a group environment. Prior research explored using different features such as locking users out of their smartphone device [52]. Minsam et al. [52] designed an application (Lock n' LoL) to help users focus on their group activities by allowing group members to limit their smartphone usage together. Lock n' LoL provides synchronous social awareness of each other's limiting behavior. Using a research study with 976 students, results showed that Lock n' LoL helped users mitigate smartphone distractions. Previous research has also gone into sharing what a person is doing on a display [43, 51]. Pradthana et al. [43] built a prototype that reveals what a user is currently doing on their smartphone on a display on the back of their mobile device. Following a ten-day trial results showed the prototype was beneficial in increasing awareness of nearby user's mobile activities while also triggering interactions with one another. Kim et al. [47] developed Let's FOCUS, an app built to help college students stay focused to their class. The app was designed to remind the students to explicitly restrict their mobile phone use voluntarily while they are in class. Results revealed the 379 students used the app to limit their smartphone usage by 9335 (24.6 on average) hours while they were in the classroom over a six week period. Cuotto et al. [15] and Paasovaara et al. [72] developed two apps, Idliketoknow and

Next2You, that are designed to encourage social interaction anomymously and via gamification between co-located individuals. Both apps exhibited signs of acting as an icebreaker to further facilitate conversation between individuals. Constantly, family meal times are distracted by personal devices [60], and thus Ferdous et al. [21] developed TableTalk, an app that takes personal devices and combines them into a shared display on the table to enrich meal time interactions. Results from a user study showed that TableTalk encouraged more conversations and socialization in the co-located family. While all these strategies are designed to reduce smartphone usage by sharing what individuals are doing on their devices in a co-located environment, none of the prior work explored how to design an agent-based solution to motivate reducing co-located smartphone usage.

Notification-Based Strategies

Oftentimes notifications can distract users from social interactions when delivered at inopportune times [63]. Prior work explored ways (i.e., when and how) to present smartphone notifications to users. For instance, Park et al. [74] investigated break-point-based notifications, where notifications are only sent to users when an opportune moment has arrived. They explored three different breakpoint styles to deliver a notification: a long stretch of silence from the group, co-located individuals leaving the table/environment, and when co-located individuals are using their smartphone. Results showed that the app was able to accurately detect the break-points, reduce notification interruptions, and encourage social interaction. Similar to the previous idea, Okoshi et al. [71] explored user interaction-based (e.g., closing an app) and physical activity-based (e.g., when a user stops running) breakpoints in users' daily life and appropriately sending notifications at these breakpoints. Results from user studies revealed that this break-point-based system resulted in a significant reduction in users workload perception. Lin et al. [73] conducted another study focusing on intelligently exchanging notifications to enhance social interactions. The authors built a system that takes social context into account and appropriately sent notifications based on this factors. Two more research studies also proposed developing an intelligent system that aims to automatically find opportune times to send notifications or prompt users to engage with content [62, 78]. They found users to engage with more notifications and content in the systems built in these research studies, in comparison to baselines.

2.4 Smartphone Agents and Effects

2.4.1 Interacting with a Smartphone Agent

There has been research done with smartphone agents in persuasive technologies to enhance users experience such as in speech and voice [101], healthcare [6, 9, 49, 54, 77, 80], and smartphone interaction [67, 95, 96]. For instance, Yamamoto et al. [101] designed a 3D-Computer Generated (CG) virtual agent that allowed users to interact with their smartphones through voice command without any delays. Results showed the agent enabled users to interact with it more naturally then existing systems as well as have a short delay in their interaction. Moreover, researchers explored leveraging virtual agents in the medical field, where the agents have been designed to provide advise regarding medical conditions to patients [6, 9, 49, 54, 80]. Furthermore, Phillip et al. [77] developed a smartphone app called KANOPEE that enables users to interact with a virtual agent designed to help with their sleep. The virtual agent is an AI program using decision tree architecture[93], to help develop a personalized sleep recommendations for 10 days for participants to follow. Results showed that participants welcomed and accepted the virtual agent concept to assist with their sleep and consequently their sleep quality reported to be improved immensely. Virtual agents have been explored in other contexts such as virtual tours and navigation. For instance, Uchiya et al. [95, 96] developed a voice interaction agent, using a 3D model GPS and Google Maps, that guided individuals through a campus tour. Study results showed that the virtual agent contributed to cost reduction at the university, reduction of time and effort required by actual tour navigators, and removed the problem of time restrictions for on campus activities. Obremski et al. [67] implemented a prototype that focused on humans interacting with an autonomous Intelligent Virtual Agent (IVA) that pretended to act as a smartphone. To my best knowledge, all the prior work on smartphone agent focused on assisting individuals to achieve certain goals. I aspire to develop a smartphone-based agent encourage co-located users to reduce smartphone activities.

2.4.2 Mediation and Intervention Techniques via Smartphone Agents

Researchers explored leveraging mediation and intervention techniques on smartphones. For instance, Webb et al. [100] constructed a mediation app used to reduce psychological distress. Similarly, Mahlo et al. [59] created a mindfulness-mediation program for older adults. Both showed signifi-

cant improvements to the persons well being after using the mediation apps. Stieger et al. [92] designed PEACH, an intervention app that is designed to coach individuals and motivate them to change aspects of their personality. They found the intervention app to be effective in changing aspects of individual's personality. In similar work, Dupuy et al. [19] developed a virtual agent app, KANOPEE2, that autonomously screened and alleviated insomnia symptoms through an intervention program and offered personalized advice and relaxation techniques. KANOPEE2 was shown to reduce insomnia symptoms using these intervention techniques. In more recent studies, Ismail et al. [41] presented a conceptual framework for agent-mediation to monitor users self quarantining to lessen the amount of work on health officers. The proposed agent would have two tasks assigned to it: checking the quarantined individual's body temperature at certain time periods and reporting if it was abnormal; and, determining through longitudinal and latitudinal data if the quarantining individual had moved to far from where they should have been quarantining. The authors revealed the agent to be a starting framework for further implementation as only using sensors was deemed to be insufficient to perform the tasks of monitoring self-quarantined individuals. Researchers also explored ways to design smartphone-based solutions to mediate a touristic experience [20, 84, 102]. For instance, Wang et al. [98] explored the mediation mechanisms of smartphones, by dwelling into their apps used as well as the stories the travellers had while travelling. Results showed that smartphones can actually change the tourists behavior by taking on a mediating approach. However, very little is known on smartphone agents using mediation and intervention techniques between individuals for co-located smartphone usage. In my research, I aim to further explore the direct use of an smartphone agent and the effects of agent mediation in co-located smartphone usage.

2.4.3 Effects of Social Entities on Individuals

Researchers have examined effects on social entities into both online (i.e., over the computer) and in-person interaction techniques between people (i.e., with a robot) and an agent. For instance, Watanbe et al. [99] ran a field study with an android robot that made conversation with visitors whom were interacting with it via multiple displays. The authors were interested in investigating which kind of functions the android robot needed in order to be recognized as human like by the visitors. Results showed that the visitors viewed the android to be human like while also suggesting the android had an effect on their social influence acting as an advertisement effect. Liszio

et al.[57] conducted a study involving integrating social entities into Virtual Reality (VR) games to enhance sociability. In a study conducted with 75 participants the authors compared the effects of another human player and a virtual agent on the player's experience. Results showed that by adding social entities, players had a decreased sense of loneliness whilst playing the game, which enhanced their experience. My designed smartphone agent can potentially be viewed as a social entity that facilitates conversations between co-located individuals. Consequently, I aim to determine whether adding in a social entity will cause any effect on co-located people. To my knowledge no previous work has explored smartphone agents, particularly anthropomorphized agents, in persuasive spaces.

Chapter 3

Study 1: Exploration of Co-Located Smartphone Usage and Activity Awareness

I started my exploration by conducting a crowdsourced study investigating people's smartphone usage, rules, trust and privacy concerns, and activity awareness when they use smartphones in the presence of their partner. Prior research has shown that crowdsourcing platforms, such as Amazon Mechanical Turk (AMT), are popular and convenient tools for conducting user studies and collecting reliable data [3]. I used AMT to run my study.

3.1 Online Survey

I created an online survey with 58 questions to collect data from smartphone users. The survey contained five sections: i) 18 questions to collect demographic information about participants and their partners (e.g., age, nationality, gender, education, and household conditions); ii) 15 questions about smartphone usage (e.g., how often, where and what types of apps), usage rules in the household, and privacy-related issues; iii) 9 questions about trust-related issues that arise when people share their smartphone usage activities with their partner and other family members; iv) 5 questions targeted at smartphone usage behavior and habits when co-located with the partner; and v) 11 questions regarding the awareness of the partner's smartphone usage and possible strategies used to share usage related information with a partner. In total, I used 15 open-ended questions, 26 single/multiple-choice questions, and 17 5-point Likert scale questions. Most of the open-ended questions were used to collect descriptive responses about co-located smartphone usage where the Likert scale questions were designed to quantify results and to obtain shades of perceptions regarding issues on

smartphone usage.The single/multiple-choice questions were primarily used to collect demographic data.

3.2 Participants and Study Procedure

I posted my survey as a Human Intelligence Task (HIT) to AMT (with a $1.00 compensation). I specified two qualifications for participants: a minimum of 70% approval rate and a minimum of 50 previously completed HITs. I also set the following requirements for the workers: they (a) must own a smartphone, (b) be either married, or in a common-law, or in a partner relationship, where (c) the partner must also own a smartphone and (d) currently live in the same household. In total, I collected 109 responses in seven days. I subsequently removed 31 responses which contained one or more unanswered questions and/or invalid answers. Consequently, I analyzed data from 78 participants (34 female, 44 male). On average, participants took 25 minutes to complete all the questions.

3.3 Data Analysis and Results

I applied a thematic analysis on the qualitative data where two researchers separately went through all the comments to perform open coding. Later they consolidated and reconciled codes into a common code set. Self-reported quantitative data were analyzed using standard statistical methods such as mean and standard deviation.

3.3.1 Demographics and smartphone usage

The majority of my participants were from two age ranges: between 24 and 34 years (28 participants) and between 35 and 44 years (29 participants). Three participants were aged between 18 and 24 years, nine between 45 and 54 years, and nine between 55 and 64 years. Only two participants were 65 years or older. Fifty-five participants were from the USA, 23 from India. On average, my participants had been in their relationship for 13.3 years. Participants and their partners had been using smartphones for 8.5 and 7.9 years, respectively. Participants reported using smartphones an average of 3.3 (SD=2.0) hours per day.

I asked participants what categories of apps they used the most. Table 3.1 shows the results (Note: participants could choose more than one app category). I observe that communication (e.g., email, text message, skype,

App Category	Usage Amount (%)
Communication	90%
Social Media	83%
Internet	85%
Location-sharing	19%
Health-related	29%

Table 3.1: Categories of apps that participants used the most, ©K. Khatra (2022)

phone calls), social media (e.g., Facebook, Instagram, Snapchat) and the Internet apps (e.g., reading news, hobby-related browsing, banking) were used the most at least once a day. Meanwhile, location-sharing apps (e.g., Glympse, Life360, Find My Friends) and health-related apps (e.g., fitness tracking, sports, or medicines apps) were used less at least once a day.

3.3.2 Co-located smartphone usage

Participants reported that they are co-located with their partner for a considerable amount of time (mean 5.9, SD=3.6 hours/day excluding sleeping time) and that they often engage in collaborative activities with their partner, such as cooking or watching movies (mean 2.2, SD=1.4 hours/day). In response to an open-ended question, participants reported various reasons for using their smartphones when co-located with the partner. Table 3.2 shows the results. In total, I analyzed 167 coded responses which can be categorized into the following five broad categories: 1) communication/ socialization with friends or family members (38% of the responses), 2) work-related activities (20% of the responses), 3) checking information and updates for own interest (20% of the responses), 4) finding information for a purpose shared with the co-located partner (13% of the responses), and 5) personal entertainment (9% of the responses). These results are similar to earlier qualitative results [68] which showed that people use smartphones in the presence of their family members to check notifications, find information, and fill time when they are bored. my results also revealed that co-located smartphone use frequently happens at home (44% of the responses), mostly in the living room and bedroom. Many participants talked about using their phones at home when co-located with their partners. " *watching a movie on tv at home and he was upset that I checked my phone.*" [P20, female,

Reason	Number of People (%)
Communication/ socialization with friends or family members	38%
Work-related activities	20%
Checking information and updates for own interest	20%
Finding information for a purpose shared with co-located partner	13%
Personal entertainment	9%

Table 3.2: Reasons for using smartphones around partners, ©K. Khatra (2022)

relationship 27 years]

Other common places for co-located smartphone use include restaurants (18% of the responses), public spaces such as in shopping malls or parks (24%), during social gatherings (7%), and inside cars (7%). All participants reported frequent occurrences (at least once a month) of their partner expressing concerns regarding their co-located smartphone usage. "*I pulled out my phone just to go on it before the food came and he complained.*" [P1, female, relationship 4 years] || "*We were in bed together and not really paying attention to what she was saying.*" [P16, male, relationship 21 years]

I coded a total of 114 responses regarding the situations (places and activities) when this had happened: at mealtime, either at home or in a restaurant (29% of the responses), while watching tv/movies together at home (16%), in public places, such as in a shopping mall (15%), in the bedroom at bedtime (13%), during on-going conversations (10%), and in some other situations such as at a social gathering or while in the car. Two participants from India responded that it had happened while being in a temple.

Participants' concerns were mostly related to the lack of attention to what they had expected their partner to concentrate on during a conversation or other activity. Sometimes they were concerned about disregarding family time and social engagement (especially when surrounded by family or friends in social gatherings). Several participants mentioned that their failure at paying attention sometimes led to frustrations and tensions between them. "*When we sit together and talk to each other in our living area at home, I go through messages in WhatsApp. That time my partner gets*

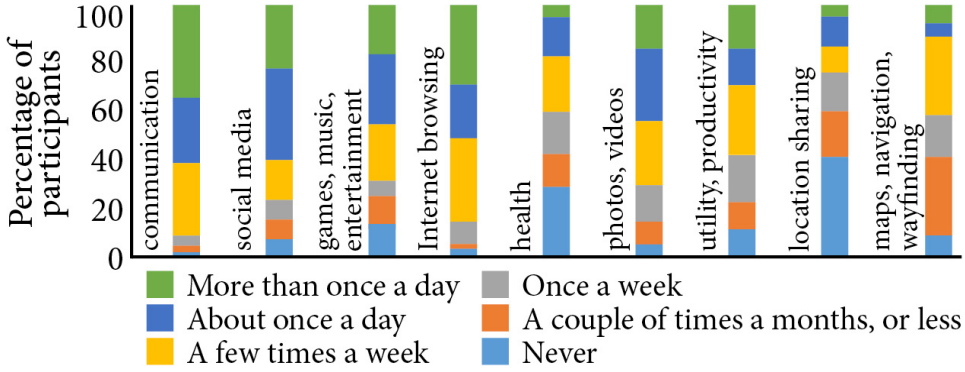

Figure 3.1: Participants self-reported smartphone application usage frequency when co-located with their partner, ©K. Khatra (2022)

irritated, thinking that I am not listening to him." [P10, female, relationship 21 years] || "*During a dinner at his friend homeI was using my phone continuously to text my friends. He signaled me not to use the phone at a get together because it seems odd when I am not involving in the event. I keep on texting my friends he raised and fought with me.*" [P21, female, relationship 10 years]

Participants reported that their partner expressed concerns about their co-located smartphone usage primarily due to disruption in their quality time, and sometimes expressed anger and annoyance. On average, participants reported that they spend 2.3 hours a day on their smartphones while co-located with their partners. For each app category, at least 30% of the participants who use those apps more than once a day reported to use them less frequently while co-located with their partner.

I also asked participants about the apps that they often use when they are co-located with the partner. Figure 3.1 shows the results. I observe that they frequently surf the Internet (e.g., reading news, browsing, banking), use communication apps (e.g., email, text message, Skype, phone calls) and social media apps (e.g., Facebook, Instagram, Snapchat). However, they rarely use health-related apps (e.g., fitness tracking or medicines apps) and location sharing apps (e.g., Glympse, Life360). The results suggest that people prefer to use communication and other related apps to connect to families and friends when co-located with their partner.

Location	Number of People (%)
Mealtime	33%
Family time with kids	21%
Collaborative activities	16%
Bedtime	12%
Social gatherings	7%
Driving	5%

Table 3.3: Locations that participants had set rules for restricted smartphone use, ©K. Khatra (2022)

3.3.3 Rules or mutual understanding on smartphone use

I asked participants questions about rules or agreements set in the household to reduce co-located smartphone usage. More than one-third of the participants (35%) mentioned having some house rules. The rest (65%) said they did not have any formal agreement, yet they shared a mutual understanding with their partner. "*We're responsible and adult enough to know when it's time to use the phone or not.*" [P52, male, relationship 11 years]

The participants who reported to have rules or agreements (43 coded responses) for smartphone use had rules based on either locations or situations. Table 3.3 shows the results. I observe that common locations of restricted smartphone use was during mealtime, family time with kids and collaborative activities. Whereas, bedtime, social gatherings, and driving were less common areas of restricted smartphone usage. "*We agreed to not use our smartphones during dinner unless it's an emergency.*" [P46, male, relationship 26 years]

Often the rules or agreements were set to ensure quality time within the family and in social gathering: "*I am in agreement with him that we do not use our phones when it's quality time for us to be together or when we're with others in a social situation, unless everyone is using them, too, for some reason (like looking up some info or playing a game together).*" [P58, male, relationship 8 years]

The rules also came from self-realization of being disconnected: "*Once me and my spouse was continuously using the phone when we were at home we realized that we didn't speak to each other. That moment we decided not to use phones unless an emergency when we both are together.*" [P21, female, relationship 10 years]

I asked the 51 participants, who did not have any rules, how they would

feel about creating them. Fifty percent of these participants welcomed the idea of having some rules for ensuring proper engagement with the partner. Twenty-five percent expressed being somewhat neutral about agreeing on rules. The remaining 25% opposed the idea of agreeing on rules. They did so as they felt that rules would intrude on their smartphone activities or that it may be an "overkill" between adults who should be able to act on their own accord. Some stated that they shared mutual respect not to use smartphones in certain situations and do not need any rules. "*We should come up with guidelines for smartphone usage that would make me feel better about our communication with one another.*" [P37, female, relationship 14 years]

The average length of relationships for the participants who have no rules was larger (avg. 14 years) compared to the participants who reported to have rules (avg. 10 years). Binomial Logistic Regression showed no significant difference in gender and relationship length between these two groups.

I asked participants whether they have any rules regarding smartphone use for other family members, excluding themselves, such as their parents (e.g., an older adult living at home with their adult children), teenage children, or younger children. Most participants mentioned that they do not have any rules for other adults in the home as they are responsible adults who do not use smartphones frequently. "*There is no rule as my mom is an aged woman and did not use phones every day.*" [P39, male, relationship 12 years]

However, 40 participants with children have strategies and rules to control the child's smartphone usage. For instance, out of 52 responses, 37% of the responses were about time-based restrictions (e.g., no more than 30 min per day), 23% were about content-based restrictions (e.g., only for games and watching YouTube videos), 21% were location-based restrictions (e.g., not at the dining table, in the bedroom or washroom), and 6% were about age-based restrictions (e.g., no phone before 8 years). Such "no phone" policies were primarily set to ensure that the children were engaged in more purposeful activities and to ensure they spent enough time with family members. Typical responses were: "*We do not allow our sons to use their smartphones in private such as their bedroom or bathroom. We also have their settings configured so their phones may not be used between 10pm and 6am.*" [P46, father of 2 children]

3.3.4 Strategies to reduce co-located smartphone usage

I also asked my participants whether they know of or used any apps or other tools to reduce smartphone use in co-located situations. The majority (67 out of 78) mentioned that they do not know of any such solutions that could either help them be more aware of each other's smartphone activities or help to reduce co-located smartphone usage. The remaining participants (11) mentioned that they are aware of apps to restrict usage time. They mentioned using iPhone's Screen Time [39], Night Mode [38], Offtime [70] to track their daily smartphone usage activities and to limit smartphone app access after a certain amount of time.

I used a 5-point Likert scale to collect participants' opinions on the importance of using apps or other strategies to reduce co-located smartphone usage. I observed that younger participants felt that it was more important to have apps or strategies in comparison to the older participants. Out of 28 participants in the age range 25 to 34 years, 17 participants expressed high importance (rating 3 or more) of having such apps or strategies, whereas only 25 of 50 participants in the age range 35 to 65+ years expressed high importance.

3.3.5 Sharing information, privacy, and trust

About 74% of participants said that they told their partner what they were doing on their smartphone when co-located at least a few times a week. I also asked them how truthful they are when sharing information. Twenty five out of 34 females and 19 out of 44 males said that they share accurate/truthful information about their smartphone activities with their partner. Participants who said they told the truth commented that they do not have anything to hide from their partner and do not want to lose the trust. "*We value honesty in our relationship, not that we do anything shady on our phones, but if we did, I would immediately inform her of anything I did, and vice versa.*" [P52, male, relationship 11 years]

On the other hand, participants who said they did not always share accurate information with their partners did so because they were trying to safeguard their privacy or ensure personal boundaries. For instance, some participants mentioned that they are not comfortable sharing financial information, business matters, photos, videos and things that they search on their phone. This is due to the sensitivity of this information, and sometimes to maintain personal space [94]. "*I might be slightly embarrassed about the random things I look up.*" [P33, female, relationship 20 years]

In a follow-up 5-point Likert question (5=very confident to 1=not confident at all), participants were asked to indicate their confidence level about whether their partners tell true information about their smartphone activities. Both male and female participants had strong confidence that their partners share accurate information with them, which reflects their average score of 4.45 (SD=0.84) and 4.68 (SD=0.79), respectively. Only six participants gave a rating of 3 or below and expressed their past experience of finding their partners not being truthful. This experience could consequently create an impact on their level of trust in the future. "*About 9 months ago my partner expressed that due to past cheating by previous partners, she felt paranoid when I was using my phone to chat with other people.*" [P8, male, relationship 1 year]

3.3.6 Smartphone usage awareness

I examined participants' awareness about exactly what their partner is doing on their smartphone and how interested they are in knowing what their partner does on their smartphone. Seventy eight percent of the participants responded that they are not fully aware of their partner's smartphone activities. In some cases, participants reported that this lack of awareness triggered misunderstanding among the co-located partners as their partners make assumptions based on their smartphone activities. A potential reason for such an assumption could be the limited information that can be seen from a distance about a person's usage activities. Similar results were found by Oduor et al. [68] who reported a lack of smartphone activity awareness among co-located family members.

I included questions on the common strategies for sharing activity awareness with co-located partners. Participants reported that such awareness was often achieved by asking questions of their partners where they responded verbally or showed their screen to their partner. This action sometimes led to frustration and anxiety among partners. "*I normally just ask what he's doing (especially if he laughs!) and he'll always tell me.*" [P1, female, relationship 4 years] || "*My partner usually gets aggravated when I ask what he is doing, because usually, he is trying to figure something out on his phone.*" [P11, female, relationship 15 years]

In exploring how interested participants were in knowing the partner's smartphone activities, I found that male participants were more interested (66% of the males were interested) in knowing what their partner is doing on the smartphone than female participants (58%). On the contrary, in a question asking about their partner's interest in knowing what they are

doing on their smartphone, I found that 86% of male participants reported their partners to be interested in knowing their activities, whereas 68% of the females reported the same. I observed a trend that this interest decreased gradually with the increase of age range. In the age range 25 to 34 years, 82% expressed interest, whereas in the age range 35 to 44 years only 70% showed interest.

3.3.7 Co-Located Content Sharing

I collected information on level (details vs. abstract) of smartphone activity information that the participants are comfortable to share with their partner and the level of information that they would like to receive from their partner. I provided them with three different levels that they could choose from for sharing or receiving: (i) detailed information (e.g., chatting with "Alex" in Facebook), (ii) an app's name (e.g., using Facebook), and (iii) activity information (e.g., playing games). Additionally, they could write any other abstractions that they might be comfortable with. I collected 119 coded responses for sharing and 120 coded responses for receiving level of information as they were allowed to select multiple levels.

Table 3.4 shows the level of smartphone usage information participants are comfortable sharing with their partner. Many participants are comfortable with providing very detailed information to their partners (37% responses), whereas others reported preferring to share only the app name (34% responses) or general activity information (29% responses). The other participants reported only feeling comfortable with providing less or no information at all. I also found that the preferred sharing level varies across apps. 37 participants mentioned that they share details when using communication apps whereas only 19 participants share details while they are browsing the Internet. I observed similar results for receiving information from their partner. Table 3.5 shows the results. Many participants indicated that they would like to receive detailed information from their partners (34% responses), whereas others expressed to receive only the app name (36% responses) or activity information (29% responses). The other participants (only 1%) reported feeling comfortable with receiving any level or no information at all.

I further asked participants to provide examples where they share smartphone usage information with different people (e.g., partner, family members). I observed that it is common to share different levels of information with different people: "*I would give less details based on how well I know the person. My partner and family get more information that colleagues.*" [P57,

Level of Information	Number of People (%)
Detailed information	37%
App names	34%
Activity information	29%

Table 3.4: The level of smartphone usage information participants are comfortable with sharing with their partner, ©K. Khatra (2022)

Level of Information	Number of People (%)
Detailed information	34%
App names	36%
Activity information	29%
No information	1%

Table 3.5: The level of smartphone usage information participants are comfortable with receiving from their partner, ©K. Khatra (2022)

male, relationship 2 years] || "*To my partner, I share all the information; to my family members, I share only app name or activity name*" [P53, male, relationship 7 years]

3.4 Discussion

Results from the survey revealed that people use smartphones in the presence of their partner even though their partner expressed concerns about the usage. In general, people can see when partners use smartphones in front of them, but exactly what a partner is doing on the phone cannot be easily inferred from an observer's viewpoint (also found by [43]). my work builds on prior work by illustrating the locations and activities in which this occurs, the rules people have setup to help mitigate issues, and how they feel about sharing usage information. Participants reported that co-located usage and asking about their partner's activities sometimes triggers aggravating situations. However, there are no known technological solutions available that would help them share their smartphone usage information with their partner while offering some degree of privacy to increase activity awareness and create shared experiences in co-located contexts.

These findings motivated me to think of a means to improve people's awareness about their partner's phone activities while co-located by sup-

porting different levels of information (details vs. abstract), such that they can make informed decisions about how to handle the situation. Additionally, prior research showed that improved awareness could help couples to stay in sync [5] and be motivated to limit phone usage and, thus, improve the quality of domestic life [58]. I recognize that awareness of a partner's smartphone activities was not desired by all participants. Some participants were satisfied with the level of information they knew about, and some were fine relying on social protocols with their partner to remedy challenging situations. Thus, a natural progression warrants an examination of design solutions that might work for people who were more interested in additional knowledge of what their partners were doing on their phone in a hope to improve social interactions. Prior work showed that smartphone activity awareness can be achieved with additional hardware instrumentation such as attaching an additional display on the backside of a phone to provide cues to smartphone activities [43]. Results revealed that users did not feel comfortable using it and were unwilling to reveal app related information due to privacy concerns. Instead, I developed an app-based solution on an unmodified smartphone to provide new opportunities to increase activity awareness among partners. With my design, CoAware, users can intuitively share activity information with various granularity levels to help avoid privacy concerns.

Chapter 4

The Design of CoAware

Informed by my findings, I designed a smartphone app, Co-located Awareness (CoAware), intended for sharing smartphone usage information between co-located partners.

4.1 CoAware Features

CoAware was designed to share users' smartphone usage information such as the number of times an app has been launched, the duration it has been used for, and the time it was initially opened. I used a foreground app checker external library [97] that allows access to smartphone app usage information. In addition, I developed a solution to directly share screens from one smartphone to another via WiFi direct. Based on these capabilities, I developed three techniques to share app usage information between two co-located smartphones with CoAware. As my survey results showed that people prefer to share information by varying degree of details about app usage, I designed the app to have three different levels of access; from very limited information which users may be more comfortable sharing (e.g., an app category) to very specific information (e.g., viewing the screen) that could possibly be more privacy intrusive. Thus, users can choose what level of sharing they and their partner are comfortable with. The specific levels are:

App Category: This access level provides users with a high-level view of app usage information, where only the types of apps being used are shown and not the app names (Figure 4.1). For instance, apps that are used for contacting other people (e.g., email, text message, skype, phone calls) are mapped to and labeled as "Communication." Commonly used apps are categorized into different labels.

App Name: In this access level, CoAware tracks the name of a running app on the co-located phone (Figure 4.2). The app name is displayed on the other phone.

Screen Share: In this access level, CoAware captures images of a phone's screen and transfers it to the co-located phone every 50ms. In

Figure 4.1: Once the access is gained to the partner's device, the partner can see the app the app category, ©K. Khatra (2022)

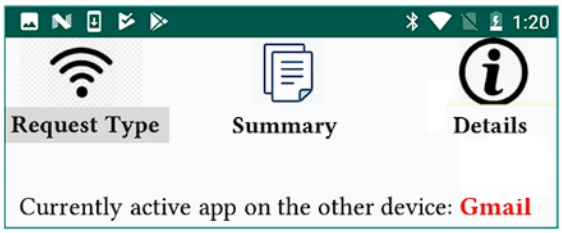

Figure 4.2: Once the access is gained to the partner's device, the partner can see the app name, ©K. Khatra (2022)

this way, co-located users are aware of the exact on-screen activities of each other (Figure 4.3).

With CoAware, when two devices are co-located, one device sends a connection request and asks permission to access App Name, App Category or Screen Share information. The receiving device shows the request in a pop-up (Figure 4.4) where the user of the device can accept or reject the request. If accepted, the sender device gains access to the app name, app category or the device screens of the other device. It also starts logging the app usage information (e.g., running app) on the receiving device. CoAware provides three notification strategies to allow co-located partners to send information through the app. I wanted to provide various levels of information exchange and control.

Message: Users can send a preset or custom message to their partner. Examples of preset messages are "It feels like you've been using Gmail for a while now, can we talk instead?" and "Hey, it's me. How are things going?" Custom messages allow users to type anything in a text box and send the text to their partner. I included this possibility to offer flexibility in terms of how users like to communicate with their partners. This messaging

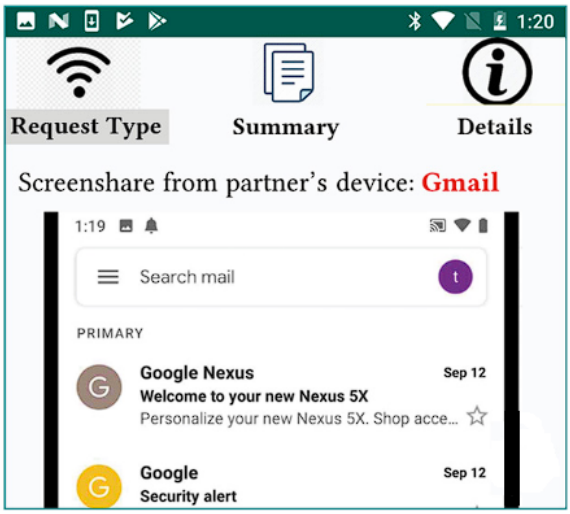

Figure 4.3: Once the access is gained to the partner's device, the partner can see a screen showing the screen content of the app that the partner is viewing, ©K. Khatra (2022)

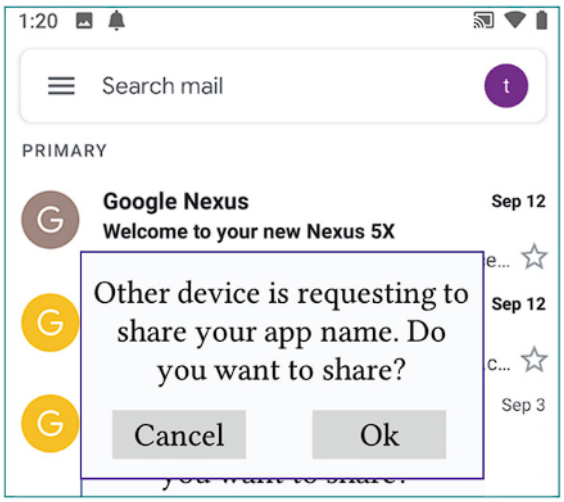

Figure 4.4: A connection initiates with a request to gain access to the partners device, ©K. Khatra (2022)

feature is similar to sending a text message; however, I hoped that preset suggestions for messages might help to create courteous exchanges between

partners and not heighten tensions. This reflects findings from my survey where some participants said they would gently ask their partner about their smartphone usage if they felt it was inappropriate.

Usage Statistics: Users can send app usage statistics such as "You have been using Gmail for 4 min and 54 seconds." to their partner (Figure 4.5). Such messages are created using the duration of the longest-running app among the currently running ones, since the longest-running app is often likely to keep the user engaged for a longer period of time. This reflects findings that some participants did not realize how long they were on their phone in the presence of others; thus, some additional awareness information could be useful to regulate behavior on one's own.

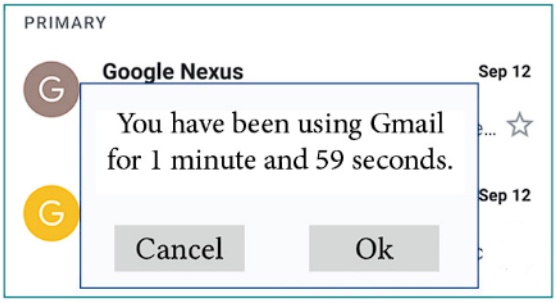

Figure 4.5: CoAware sending usage statistics, ©K. Khatra (2022)

Close Request: Users can send a request to close the currently active app that their partner is interacting with. The partner sees a prompt such as "May I request you to close Facebook?" or "I was hoping you could close Gmail. OK?" (Figure 4.6). The partner can cancel the request and continue using the app. If the partner agrees (tapping the Ok button), the app shows a 30-second countdown timer. Rather than closing the currently running app instantly, the time is given to let the person finish the current activity [10]. When the 30 seconds are over, CoAware closes the currently running app. my goal here was to make the app closing somewhat graceful and delayed and less of an immediate interruption. This reflects findings from my survey where, again, some participants said that they might ask their partner to change their behavior on their smartphone. I recognize that causing actions to occur on someone else's phone may come across as being strong or overly assertive to some people. I wanted to explore this idea to see how people would react to it in further studies.

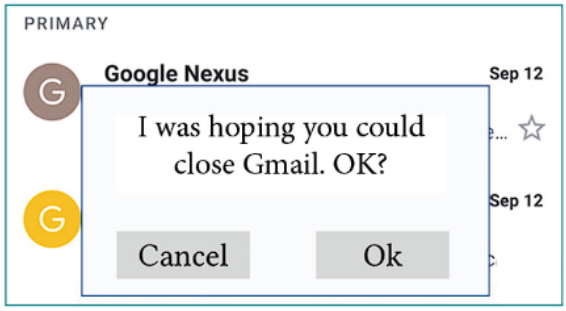

Figure 4.6: CoAware initiating a close request, ©K. Khatra (2022)

Using the Summary tab, one can see the usage statistics for the apps. The summary includes the app/category name, the total time the app or category has been used and the number of launches since the current connection was established (Figure 4.7). If the access level App Name or Screen Share is given by the partner, then one can see the app names. The access level App Category only allows one to see the app categories. Using the Details tab, one can see more detailed information about individual apps or app category launches (depending on the access level), such as the name, launch time, and duration of use (Figure 4.8). Overall, I recognize that not everyone will find the features I propose in CoAware to be useful. Some may find them to be overbearing, some may find them to be not needed at all, and some may find them to suit their needs well. This is as expected and purposeful such that I could explore my design ideas more and see what reactions participants would give with a fully working system that provides such options.

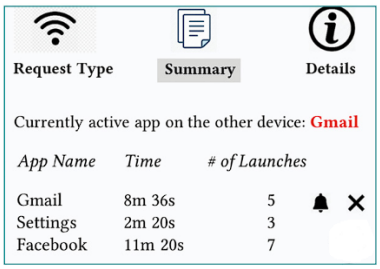

Figure 4.7: CoAware showing a summary, ©K. Khatra (2022)

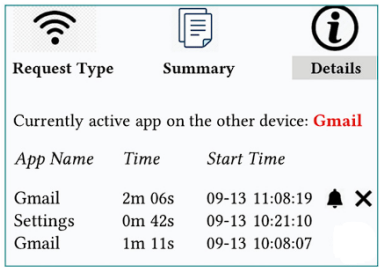

Figure 4.8: CoAware sharing detailed information about apps used since the connection was established, ©K. Khatra (2022)

4.2 Implementation Details

CoAware was built on Android SDK 4.4 and leverages smartphones' WiFi Direct to establish peer-to-peer connections between two smartphones. I used WiFi direct as this technology allows two devices to connect directly without requiring them to connect via Wi-Fi routers or wireless access points, thus enabling sharing information between co-located users in any location (e.g., at home, park). Prior research has shown that smartphone activity can be shared with others by instrumenting the device (e.g., attaching an additional display to the back of the device) [43] which can raise privacy concerns due to the visibility of private content in some common contexts (e.g., public places). Hence, I designed an application solution that does not require any additional hardware instrumentation.

Chapter 5

Study 2: Explorations of CoAware

I conducted a study in a lab setting as an initial attempt to get feedback from participants about CoAware. Note that the lab study was designed to gain insights about the benefits, privacy risks and opportunities of CoAware and generate directions to guide future researchers while designing apps to increase activity awareness among co-located people. I investigated users' feedback on the three access levels for sharing app information amongst co-located partners and explored their opinions on the three notification strategies provided by CoAware. Additionally, I collected participant feedback on privacy issues and on how CoAware creates awareness and I asked for general feedback on CoAware's features. Naturally, I could have explored my ideas using a field study where participants from various socio-cultural backgrounds could have tried out CoAware over a prolonged period of time. I did not use this approach given that CoAware is still at an early design stage. Field studies bring the risk of participants not trying out all of the features within a design. I felt it was more reasonable to gather initial participant feedback such that the general ideas presented in CoAware could be assessed to understand which may hold the most merit. Then, either CoAware or other applications like it could be created and explored through longer-term usage. The caveat is that my study does not provide generalized results across a range of real-world situations. I do acknowledge that a further field study is required to evaluate the app in the wild.

5.1 Participants and Procedure:

I recruited 22 participants (11 couples) from the local community (a large city within North America) to participate in the study. Two participants were 18-24 years old, 11 were 25-34 years old, 4 were 35-44 years old, 2 participants were 45-54 years old, and 3 participants were 55-64 years old. All participants were smartphone users and have been in their partner

relationship for an average of 9.5 (SD=5.7) years. None of them had experience using tools to reduce smartphone usage or to support the awareness of someone else's smartphone use.

I used two smartphones, Google Pixel 3 and Google Nexus 5, for the study. I first showed participants how to use CoAware. Next, participants were given the following two tasks to complete:

Establish a connection: One person (sender) sends a connection request and the other person (receiver) accepts it.

Access information: The sender accesses the app name, app category, and screen on the receiver's device while the receiver 1) browses information on an e-commerce website (Amazon) to find a suitable camera costing less than $500, 2) finds a rumor/gossip about their favourite actor/actress, and 3) plays a game of their choosing. Once the tasks are completed, the participants switch roles as sender and receiver and repeat the tasks.

I then used a questionnaire to collect their opinion on the access levels and notification strategies to create co-located smartphone usage activity awareness, privacy concerns related to CoAware, and design suggestions to improve the app. I asked participants close-ended questions using 5-point Likert scales regarding (Q1) the usefulness of the three access levels in creating awareness about their partner's smartphone activities, (Q2) the usefulness of the three notification strategies to motivate them in reducing co-located smartphone usage, (Q3) their comfort level when receiving a notification from their co-located partner (for each of the three notifications strategies). Additionally, they were asked open-ended questions about privacy and awareness issues. In the end, I also asked to provide feedback and suggestions regarding CoAware's features. A session lasted approx. 40 min. in total. I used thematic analysis to analyze qualitative responses where I iteratively reviewed the responses to look for main themes.

5.2 Results

(Q1) Figure 5.1a shows the mean rating on how useful the three access levels were to create awareness of partners' activities. I found a mean rating of 3.91 (SD=0.53) for App Name, 3.0 (SD=0.93) for App Category, and 4.14 (SD=0.89) for Screen Share. I observed that Screen Share and App Category were rated more useful in creating an activity awareness than App Category. (Q2) Figure 5.1b shows the mean rating for the usefulness of three notification strategies to motivate reducing co-located smartphone usage was 4.18 (SD=1.05) for Message, 3.27 (SD=0.83) for Usage Statistics, and 2.55

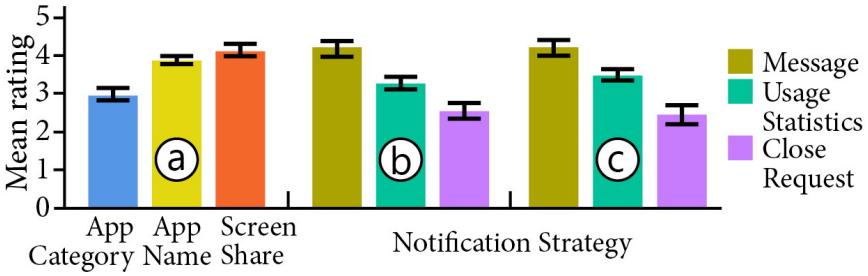

Figure 5.1: Mean rating for (a) the usefulness of the access levels, (b) creating activity awareness with notification strategies, and (c) the usefulness of the notification strategies, ©K. Khatra (2022)

(SD=1.18) for Close Request. (Q3) Figure 5.1c shows that participants were more comfortable receiving a notification with Message (4.18, SD=1.05) and Usage Statistics (3.5, SD=0.9) than with Close Request (2.5, SD=1.3).

In the open-ended questions about privacy and awareness issues, participants expressed that CoAware would be helpful to maintain their time commitment to each other, create more smartphone usage awareness so that they do not interrupt their partner during an important ongoing activity, and that Screen Share would help them during co-located collaborative activities such as sharing information with others. "*[CoAware] can be very useful for creating awareness as it allows us to check what other has been doing, especially when he is on phone for a long time.*" [P7, female, relationship 5 years] || "*The app will help when we want to show something to each other but sitting different places in a room.*" [P3, male, relationship 5 years]

Additionally, participants mentioned that there are other potential use cases for CoAware (e.g., sharing information with their partner, monitoring their children's smartphone usage). "*Sharing feature is useful as I can show photos and videos to my wife; I can share the game that I am playing to my son.*" [P18, male, relationship 13 years]

Participants also expressed privacy concerns regarding the Screen Share. For instance, two females mentioned that they used some apps to track their health-related issues which they might not feel comfortable sharing. Others wanted to have a personal digital space away from their partner which they did not want to be intruded in, as this might create stress and tension in family life. "*It will hamper my privacy, I may not feel comfortable at all for sharing screens of my messages and emails*" [P4, female, relationship 5 years]

Participants provided suggestions to improve CoAware. For example, instead of showing pop-ups, they suggested using standard notifications that commonly appear at the top of the screen. Six participants also suggested that partners should be allowed to only send a fixed number of notifications within a certain time (e.g., 10 notifications per day). Some participants wanted more notification styles and strategies or more statistics to better motivate the partner to engage with them. Two participants also felt that instead of sharing the entire screen with their partner, a blurred image or custom screen area could be shared as this would protect privacy.

Chapter 6

Design of Smartphone-based apps

I will now move to the second phase of my thesis which is focused around results of the first phase and then comparing an updated version of the text-based app with a smartphone agent-based app that plays a role in communication facilitation between partners.

6.1 Interpretation of Results

Based on the results on Phase 1, I decided on two main factors that needed to be explored. The first being that participants found some features of the app to be too intrusive, most commonly screen share and screen control, and thus wanting them to be removed. I figured the easiest way to handle this complaint by allowing app app name to be shared between couples and disable any other type of information sharing on two smartphones. I hypothesize that this would not only solve this problem but also be a good solution to reduce any further issues that could arise. CoAware also didn't facilitate communication between couples as much as I desired it to. Therefore, I explored smartphone-based agents which are designed to interact with a human like a human and be effective for interventions and mediations such as promoting physical activities, or to reduce psychological distress. Little is known about leveraging smartphone-based agents to play a role in communication and facilitate conversation between co-located individuals. Thus, I introduce a smartphone-based agent that acts as a conversation facilitator between co-located individuals. Following, I compare the effects of agent mediation on communication dynamics around co-located smartphone usage in couples in contrast to a text-based notification approach. At the time I wasn't fully aware of which direction the conversational agent may influence communication.

6.2 Design

The goal of this phase is to explore the effects of agent-based mediation on communication dynamics among co-located couples. In addition, I want to compare the results of agent-based mediation with a text-based approach, which I discuss below.

6.2.1 Agent-based mediation

Agent-based mediation involves a smartphone agent (i.e., an app) designed to facilitate conversation between individuals. More specifically, I designed the app simulating an agent playing a human role in exchanging information between couples. The agent is given a name (i.e., Ana) with an avatar. In addition, the agent can share information about couples' smartphone usage, such as how long they have been using smartphones and suggest them to be engaged with their partners. When sharing information, the agent-based app reads messages out loud on users devices, in addition to showing the same information with text notifications. Further, the messages exchanged between the co-located individuals differ depending on the app. For instance, the agent-based app is more structured towards the mediating agent providing the message. An example message includes "*Your partner wants to let you know that you have been using <appname>for X minutes and X seconds*" which is sent with both voice and text. Thus, the agent-based system is designed with the ability to anthropomorphize and act as a communication facilitator between partners.

6.2.2 Text-based approach

A text-based approach involves no facilitator or social entity intervening in conversation between individuals. This approach is tailored towards partner-to-partner communication via standard text while supporting similar features that were developed for the agent-based system. For instance, users can send information about their partner's smartphone usage which shows on the partner's device as a text notifications ("*You used <appname>for X minutes and X seconds*"). Thus, there is no communication facilitation involved, other than what the individuals do themselves.

6.2.3 Application Development

I developed two smartphone applications (i.e., apps) to support a set of features for both agent and text-based approaches. I used the Android OS

platform to develop the apps. The apps' leverage Google's Firebase Realtime Database to connect and exchange information between two devices. I also used the database to store device-related information such as their locations (i.e., latitude/longitude) and the currently active app on the device with duration. I use an Android foreground app checker library [97] to access app usage-related information such as the currently running app with duration. Both apps store additional information, such as the time when an app is launched, when a connection request is sent to establish communication between devices, when users exchange information with each other (e.g., ping their partner or share usage stats), and when they end the connection between two devices. Note that there are other existing approaches, such as using Bluetooth or WiFi direct for exchanging information between two devices. However, I decided to use Firebase Realtime Database as it offers an efficient solution while causing minimal connection-related issues [1].

Establish Connection

To start exchanging information, one device first sends a connection request to another device (Figure 6.1). As I intend only to share information

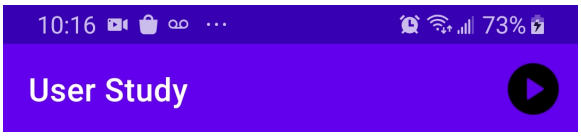

Figure 6.1: Upon clicking the play button, the background service starts, ©K. Khatra (2022)

while the two devices are co-located, I used distance-based co-location (i.e., two devices within 100m) which is also used in previous studies [30]. Once a connection request is initiated from a device, the app checks the Firebase Database to calculate whether the other device is within 100 meters and sends a connection request to the other device accordingly. The device receiving the connection request then shows the request as a notification (Figure 6.2).

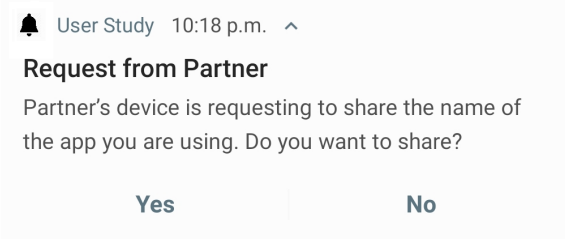

Figure 6.2: Connection request text in the text-based app, ©K. Khatra (2022)

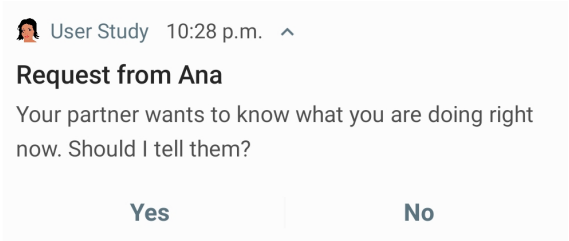

Figure 6.3: Connection request text in the agent-based app, ©K. Khatra (2022)

A user can then either accept or reject the request to share information. Once a partner accepts a connection request, the app displays a connection status *Permission given: Yes* at the bottom of the screen, indicating that their partner has given them permission to exchange information via the app (Figure 6.4).

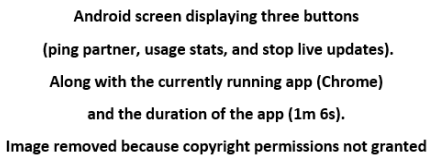

Figure 6.4: Currently running app name and duration, ©K. Khatra (2022)

In addition, both apps show whether two devices are within the 100-meter *Within Range: Yes* at the bottom of the screen. Once the connection

request is accepted, the sending device can now see the receiver's device currently used app name as well as the duration it has been running for (Figure 6.4). At the bottom of the screen, the app will show whether or not the other device has given them permission to access the information as well as notify them if they are within range of one another (Figure 6.5).

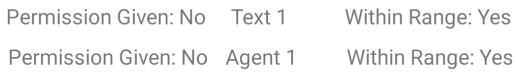

Figure 6.5: Shows permission given and if two phones are within range, ©K. Khatra (2022)

In addition, with the agent-based app, once a user sends a connection request, the receiver prompts with a voice command asking if they are interested in knowing what their partner is doing now (Figure 6.6).

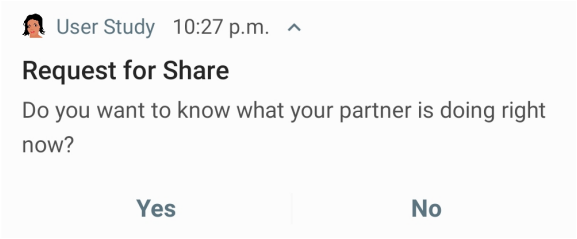

Figure 6.6: Agent-based app: an agent asks if users are interested in knowing what their partner is doing, ©K. Khatra (2022)

This is different from the text-based app, where the user has to manually click on a button to know what their partner is doing. A user can terminate an ongoing connection between two devices by pressing the "Stop Live Updates" button on the user interface. Once the connection is stopped, the app also displays a connection status *"Permission given: No"* at the bottom of the screen, indicating that their partner has stopped sharing information (Figure 6.7 - text-based app , Figure 6.8 - agent-based app).

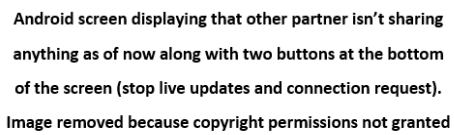

Figure 6.7: Text-based home screen after partner has stopped sharing, ©K. Khatra (2022)

In addition to the functionalities discussed above, I designed the following two features:

Usage Statistics

Both apps allow users to send information about their partners' smartphone usage (i.e., the time that their partners have spent on an app) via smartphone notifications, though, this feature differs slightly for the text and agent-based apps. As mentioned before, the text-based app is centered around a direct conversation between couples via text, whereas the agent-based app is centered around the agent mediating the conversation.

Ping Partner

Another feature of the apps is the option to ping their partner with a preset message. I designed a set of preset messages to enable fast communication between couples without requiring them to type. Text-based messages are more styled for day-to-day communication between couples via text. Example message includes: "It feels like you've been using ¡appname¿ for a while now. Can we talk instead?". For the agent-based app, the messages were intended to give couples the impression that the mediating agent is taking charge of the conversation. An example message for the agent-based app includes: "You have been using ¡appname¿ for a while. Want to talk to your partner instead". As mentioned previously, both messages are sent as notifications; however, agent-based messages use audio to read the text aloud.

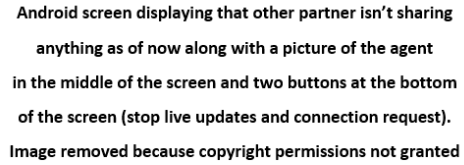

Figure 6.8: Agent-based home screen after partner has stopped sharing, ©K. Khatra (2022)

Chapter 7

Study 3: Explorations of Agent-based and Text-based Apps

I conducted a between-subject design study exploring the effects of agent mediation on communication dynamics around co-located smartphone usage and compared the results to the text-based approach.

7.1 Participants

Twenty-four participants (i.e., 12 couples) were recruited from the local community (a large city in North America) to participate in the study. I only recruited participants that used Android phones, and commonly were co-located with their partner after work or weekends. Each couple was compensated with $100 for their participation.

Two participants were 19 years old, 13 were 20-30 years old, eight were 31-40 years old, and one was 41-50 years old, with an average age of all participants being 28.8 (SD=6.0) years old . All couples had been in a relationship for at least two years, with the average length being 4.8 (SD=2.8) years. They reported spending an average of 7.5 hours (SD=1.5 hours) co-located with their partner per day, with most of them mentioning that they spent more time together on the weekends. In addition, they reported owning a smartphone for an average of 9.8 (SD=3.3) years while spending an average of 4.4 (SD=1.9) hours per day on their smartphone.

7.2 Procedure

People who had expressed interest in participating in the study received a consent form which included study details. Once they signed the consent form and returned it to one of the authors, the first meetings were scheduled. Due to the Covid-19, I scheduled the meeting online via Zoom, where I

met each couple individually (i.e., two people in a group at the same time). Six couples were randomly selected to use the agent-based app while the remaining six couples used the text-based app. During the meeting, I explained the study goals, installed the app, and showed how it worked. The participants were asked to use the app for seven days. During this time, the app automatically logged user interactions and activities with the app on the Google's Firebase Realtime Database. After seven days, I set up another Zoom meeting to conduct an exit interview with each couple individually. I used a set of interview questions focused on three main areas: i) questions related to general couple relationships (e.g., time spent together), ii) experience of using the app, and iii) the effects of the app on their co-located smartphone usage during the study period. All of these questions were asked as open-ended questions, with follow up questions being asked in case more information was needed. Each interview lasted approximately 30 minutes.

7.3 Results

I used thematic analysis to analyze qualitative responses, where I iteratively reviewed the responses to look for main themes. The iterative process was done as follows: analyzed the text-based interviews and agent-based interviews separately, looking for any major themes that existed in the answers; viewing the themes as a whole between the two and then generate a major theme list that would be used to compare the two sets of results; finally, looking at the results once again for the text-based and agent-based apps with the major themes in mind and identifying sub-themes that existed within them, which are to be used as the comparison tool in this study. Two researchers performed the coding, followed by redefining them in a consultation with the entire group (three researchers) involved in the study. In addition, I report on quantitative data collected during the study period.

I first looked at couples' responses to a few preliminary questions related to smartphone usage in co-located situations. I found that they expressed concerns about their partner's co-located smartphone usage, which was also reported in prior studies [30, 69]. Six out of twelve couples stated that their partner had previously complained about using smartphones in co-located situations. Four couples mentioned that these cases primarily occurred right after work or before bedtime. One participant stated: "*Many times, right after work, my partner will be on their smartphone for a long time, which created frustrations among us.*" [C1, Partner 1, relationship 6 years] They also mentioned that when using phones for a long time, they occasionally

requested others to stop using their phone and engage in collaborative activities. I next explore the effects on agent and text-based systems on their communication dynamics.

The following sections report on couples' responses that are grouped into three main themes: *Effect on Interpersonal Relationship*, *Effects on Phone Usage Patterns*, and *Effects on Verification Behavior Patterns* which I discuss below. In addition, I report on the privacy considerations and other concerns regarding the apps that participants shared with us.

7.3.1 Effect on Interpersonal Relationship

I asked participants questions on how the app promoted co-located interactions, and how they used the app to be aware of their partners activities. Thus, aiming to explore how the app effected the partner's relationship dynamic. In the next section, I will first discuss the results that I observed for the text-based app and then I introduce the effect that was observed with the agent-based app.

Text-Based App

The text-based app had 4 major sub-themes that I observed as having an effect on couples relationship: *Co-located Usage Awareness*, *Time and Focus Management*, *Building Connections*, and *Starting and Mediating Conversations*.

Co-located Usage Awareness: Participants mentioned that being aware of what each other were doing on smartphones had an effect on how they interacted among one another. The effect was seen in: (i) partners' app usage awareness, and (ii) their own smartphone usage. First, the app allowed them to know what their partner was doing on their smartphone and follow up with them, when necessary. One participant commented "*I was worried about my partner being on the phone for long, and it was nice to check and see what they are doing.*"[C8, Partner 1, relationship 2 years] Secondly, being aware of what each other were doing on their smartphone also had an effect on participants themselves. They expressed that they were more aware that their partner would be checking up on them and were more cautious about their phone usage. "*I was worried throughout the day because I told her I would be busy... I start using WhatsApp at certain points and she sees that and sends a notification and I get worried.*" [C1, Partner 1, relationship 6 years]

Time Management: Participant's expressed that the app helped them

to manage their time better in different ways such as engaging with their partner more often, and be more on-time. For instance, the app allowed their partner to trigger notifications when they were using phones for a long time. This eventually helped them to stop using their phones and engage with their partner. One participant mentioned: " *I was co-located with her and doing something on my phone, and I will get a notification... I need to give her some of my time as well."* [C1, Partner 2, relationship 6 years] In addition, the app also helped them to manage their time better in daily activities and be on time. Two couples mentioned the app helped them stay on-time with activities they were supposed to do together. "*I was taking too long to get ready as I was busy with my phone, and my partner pinged me through the app. I felt that I had to hurry up as we had somewhere to go."*[C9, Partner 2, relationship 5 years]

Building Connections: The app had an effect on strengthening couples relationships by allowing them to connect easily via smartphones - which are not not present on other apps. In addition, the app provides them with usage stats notifications - which help them to be aware of others activities and connect with them accordingly . For instance, participants mentioned that the app was a nice compliment to building connection as it allowed them to connect more easily which is commonly not offered in other apps. "*It was nice to keep track of her and seeing what she was doing on her phone and then I could send a message to link up later which helped to improve the connection that we already had."* [C1, Partner 2, relationship 6 years] In addition, the usage statistic's notification was also found to be a valuable asset in building this relationship by providing one another with time spent they spend on their smartphone. This helps them to be more connected with each other by triggering them to do more collaborative activities. "*My partner spends a lot of time on the phone... I sent him a usage statistics notification to stop what he is doing and go shopping or watch a movie."* [C1, Partner 1, relationship 6 years]

Starting and Mediating Conversations: Participants voiced that the app acted as an entry point to starting a conversation and mediating it by using the features of the app. They mentioned that the app allowed them to formulate queries about their partners smartphone usage which they could further use to mediate conversations with their partner. One participant commented, "*My partner was listening to music and reaching out and being like, oh, you're listening to music. What song are you listening to? And having a conversation about that."* [C12, Partner 2, relationship 2.5 years]

Agent-Based App

Similar to the text-based app, the agent-based app had an effect on couples' relationship. However, I observed two new sub-themes that were not seen in the text-based app: (i) participants perception of the agent as a third party and (ii) the agent's role for mediation in communication between the couples. First, I will look at two sub-themes that were similar then discuss the two that were different.

Co-located Usage Awareness: Similar to the text-based app, the agent-based app had an effect on promoting app usage awareness. The app helped participants to be more aware of what their partners were doing on their phones. One participant mentioned "*It does really promote co-located interaction because instead of me asking my partner each time, the app does instead and brings more attention to the app usage.*" [C6, Partner 2, relationship 4.5 years] Furthermore, by providing more co-located smartphone usage awareness between one another the agent-based app helped in individual's relationship dynamics. Participants mentioned that the app helped to reduce any aggravation between couples. "*There has been a lot less pent-up aggravation due to the app being used. We can monitor each others smartphone usage through that and not have to constantly ask each other.*" [C3, Partner 2, relationship 2 years]

Starting and Mediating Conversation: The agent-based app also served as an entry point into conversations among couples. Three couples mentioned that the app helped them find ice breakers for their conversation as well as serving a reminder to engage in conversation with their partner. One participant mentioned: "*The app tells you to stop whatever you are doing and focus on what is important. I am giving my partner less attention - thus I need to pay her more attention.*" [C6, Partner 2, relationship 4.5 years]

Agent as a Third Party: Unlike the text-based app, couples viewed the agent as a third party mediating their relationship. Interestingly, I observed that participants received the agent as a third party both positively and negatively. A few couples viewed the agent positively where they considered the agent as another social entity mediating conversations among them. They expressed that the agent-version was not just a basic app sending them notifications, it is a third party, conveying messages about their partners intent to them. A participant explained "*I really liked that it was a third party, it wasn't just the app saying, 'oh hi I want to spend time with you', it was your partner.*"[C3, Partner 2, relationship 2 years] On the contrast, two participants viewed the agent negatively where they thought that it was unorthodox for a third party to invade their relationship. Instead, they

wanted to connect with their partner directly (e.g., via texting) which they considered being more effective. One participant mentioned "*It was a little weird for a third person to kind of make that happen. direct texting would be more efficient.*"[C11, Partner 2, relationship 2 years].

Mediation Support of Communication Request: The second effect that differed in comparison to the text-based app was that the agent was viewed as providing mediating support in communication between couples. The support was seen in two different ways: partners talking more freely with one another and agent reading notifications for them out loud. Firstly, this communication support enabled participants to talk more with each other as it wasn't them directly sending the other person a notification it was the "third party" (i.e., agent) who was sending notifications. Two couple's commented that they often get annoyed when they send notifications to their partner and enjoyed how the third party agent kind of took this out of their hands. One participant explained "*I get really annoyed when my partner asks me to hangout at certain times, and when I get the popup that your partner wants to hangout, it was nice that it was coming from someone else.*"[C3, Partner 2, relationship 2 years] From the logged data, I observed that the agent-based app pinged couples 50 times and sent usage stats 45 times. Meanwhile, for the text-based app pinged couples 176 times and usage stats 71 times. Thus, contributing further to the fact the agent-based app was used less to send notifications as it wasn't needed as much. Furthermore, the agent-based app also provided a entry into conversation in couples as the notification style was welcomed. Participants explained they liked how the app reads notifications out loud for them. "*...to have an app that like makes this statement like I've been seeing you on your phone for a while, do you want to hang out with me? - it removed a sense of judgment from my partner.*"[C3, Partner 1, relationship 2 years]

7.3.2 Effects on Phone Usage Patterns

I asked participants questions on how the app changed their own behavioural patterns throughout the course of the study, aiming to explore how the app effected their behavior before taking part in the study and during it. Throughout the course of the study, participants observed that the app had an effect on their phone usage behaviours. These included immediate behavior changes in their daily life routine.

Text Based App

In the text-based app, two of the behavior changes induced included a sense of guilt, and concentration.

Guilt: Participants, in general, expressed that the app triggered feelings of guilt during the study period for their smartphone usage behavior. The app had features, such as ping partners and usage stats, which made them be aware of their smartphone over usage, especially in co-located situations. Additionally, they mentioned that they were aware that their partner could monitor their smartphone usage through the app - which eventually affected their behavior. Four participants said they had felt a sense of guilt when they weren't engaged with their partner. "*The notification made me feel guilty when I wasnt hanging out with my partner."* [C9, Partner 2, relationship 5 years] Next, one participant mentioned they noticed a sense of guiltiness as they felt as though they were being spied on. Thus, they took it upon themselves to find more times to change what they were doing to spend time with their partner.

Concentration: The app served as a vessel for participants to be focused on tasks they needed to do without being distracted by their phone. Thus, the app allowed them to be more productive and helped them to be more organized. For instance, one participant mentioned "*Maybe you've spent a lot of time on the phone, then you get a notification...I've spent a long time doing online searching and it's time for me to get back to work."* [C1, Partner 2, 6 years] Another participant noted that the usage stats notification played a role in them remembering their plans for the day. "*At points I realized that I spent an hour my phone and she is just sitting next to me. And, when I receive the notification, I remember we have plans to go shopping... and stop what I am doing and refocus on whatever I am supposed to do with my partner."* [C1, Partner 2, 6 years]

Agent Based App

In accordance with the text-based app, the agent-based app also served to help participants concentrate on tasks at hand. However, I observed a different theme that was not seen in the text-based app - participants felt more inclined to reduce their smartphone usage while using the agent-based app.

Concentration: Similar to the text-based app, participants viewed the

app as a vessel to be more focused on tasks needed to be completed. This is primarily due to the notifications that they received through the app which eventually encouraged them to be focus on activities that they should do. For example, one participant stated "*The app kept reminding us to get our focus back on doing things that are important because we found our we are spending too much time on our phones and less between ourselves.*"[C6, Partner 1, relationship 4.5 years]

Reducing Smartphone Usage Participants using the agent-based app mentioned that the app served as a factor in reducing their smartphone usage over the course of the study. The app allowed couples to see each others smartphone activities and allowed them to send notifications if needed - which eventually served as a reminder to reduce smartphone usage in many situations (e.g., meal time). One participant said "*Previously I had anxiety when my phone wasnt near me. Throughout the study I kept my phone at least a hands length apart from me.*"[C3, Partner 1, relationship 2 years]. Additionally, during meal times participants were encouraging themselves even more to put down their smartphone. "*If we are having breakfast together, I have been trying to put the phone face down away from me.*"[C3, Partner 2, relationship 2 years] This is also supported from the logged data where I found that the agent app was opened 312 times while the text-based app was used 595 times, thus invoking less situations with the agent-based app to check on their partners' smartphone usage.

7.3.3 Effects on Verification Behavior Patterns

I was interested to explore how the verifying features (i.e., being able to see how long and what their partner had been using an app) of the app effected their smartphone usage activities. Thus, I asked participants questions on how they used the app to check their partners smartphone usage.

Text-Based App

Participants using the text-based app expressed that it helped them be aware of what their partner was doing, contribute to limiting their own self-usage, and validate the smartphone usage of their partner.

Attentional Awareness Participants stated that they were more attentionally aware of what their partner was doing during the study. In contrast to before using the app, the app brought a whole new level of smartphone

activity awareness amongst one another in the relationship. A participant mentioned "*The app brought more attention to me to see what my partner was doing on his phone throughout the day.*" [C9, Partner 1, relationship 5 years]. Couples also specified they would use the app to try and pry away their partner from being glued to their phones by sending a notification to them instead of saying it out loud.

Limiting Self-Usage I also observed that the usage stats notification of the app contributed to participants to limit their own smartphone usage. After receiving a usage stats notification, participants would often stop using their phone right away whilst also reaching out to their partner."*I like how the app is limiting your time. Maybe you have spent a lot of time on WhatsApp or a different app it will alert you that you have spent a lot of time on this.*" [C1, Partner 1, relationship 6 years]

Validating Usage of Each Other Participants also used the app to validate what their partner said they had been doing in two different ways: (i) to check if their partner was being truthful about their smartphone usage and (ii) to form a closer bond between them. Oftentimes, participants would check the app immediately after their partner had told them what they had been doing. One participant explained"*Is she lying to me because she told me she was doing a different thing then I check the app and she is doing something else?*" [C1, Partner 2, relationship 6 years] Also, another participant mentioned that the app usage feature can form a closer bond between the two because of the ability to determine the truth.

Agent-Based App

I observed the verifying behaviors that the app served was mainly the same across the text-based app and agent-based app. Both contributed to being more aware of what each other were doing and also limiting their own usage. The minor difference lied in the fact of verifying each others usage. Instead of having the app ask out loud what their partner was doing, two participants stated they would rather just ask them in person themselves, and thus preferred direct conversations.

Attentional Awareness As was the case with the text-based app, participants communicated that the agent-based app brought more attention to what each partner was doing on their phones. For example, a participant explained "*Instead of me asking my partner each time they are using their phone the app helps to do it instead and brings more attention to the app*

usage." [C6, Partner 2, relationship 4.5 years]

Limiting Self-Usage Participants also viewed the agent-based usage stats notification to help limit their smartphone usage. Participants mentioned the usage tracking feature of the app contributed to this limitation. "*Me and my partner can keep track of how much time we spend on the phone and stop using it accordingly."* [C6, Partner 1, relationship 4.5 years]

Direct Conversations Two participants using the agent-based app explained they would rather ask the person out loud what they had been doing instead of the agent saying it for them. Both participants clarified that this was due to them having a very close relationship, where they aren't concerned of what each other are doing on their smartphone. They mentioned they found that the validating factor behind the agent was weird. An example of this was a participant mentioned "*Id rather just use the sentence via my tongue instead of having a third person say it."*[C5, Partner 1, relationship 7 years], In terms of trying to check what their partner was doing another participant mentioned "*If I want to know what he is doing on his phone I would rather just ask him."*[C5, Partner 2, relationship 7 years] However, there were participants that mentioned the validation of usage via checking the app was beneficial to them as was the case in the text-based version.

7.3.4 Privacy Considerations

I was interested in exploring what features of the app could cause privacy-related concerns and how this could be changed in the future. Thus, I asked participants questions about how comfortable they felt sending and receiving notifications using the app, their concerns over how the app handled data, and any privacy concerns. I found that participants were generally comfortable with how the notifications were sent while showing no concerns about the app using location data to determine their co-location. In addition, participants were generally not concerned about the privacy aspect, as the app only tracked standard data such as the name of the app they are using with duration and didn't go into too much detail (e.g., app content). One participant mentioned "*It doesn't take sensitive information like passwords or cards and therefore I felt safe using it."*[C12, Partner 2, relationship 2.5 years] For the trust aspect, one participant mentioned they weren't hiding anything from their partner so they were fine with sharing their smartphone usage the information.

7.3.5 Others

I asked participants if they would like a fully automated AI agent in the future, covering more features such as real-time notifications to couples on their app usage in co-located and non-co-located contexts. Participants said they are open to an AI agent that intrudes in their activities and relationships to a certain extent, specifically, not crossing a boundary. For instance, one participant expressed that AI agents could potentially abuse notifications by sending them frequent messages when they use smartphones for longer. Another interesting result I found was that the hearing the voice out loud startled one of the participants in contrast to a simple notification. One couple even mentioned that they were so zoned in on their phone, they couldn't even hear their partner talk but once the agent voice notification came thru they regained focused and talked with their partner.

Chapter 8

Discussion and Design Recommendations

I will first discuss discussion and design recommendations for Phase 1 of this study. Through my studies, I was able to uncover a range of ways that applications like CoAware should be designed, based on its strengths and weaknesses.

Ensuring personal digital space: The participants' lower comfort ratings when using Screen Share illustrate that there is often a personal digital space among partners which they typically want to preserve. Thus, I suggest that applications like CoAware should focus on sharing higher-level or more abstract information (e.g., the app name) instead of sharing very detailed information such as the screen content. Low-level information akin to what I provided as one feature within CoAware is likely too much for many people and could inadvertently create greater tensions between partners.

Level of access: Participants expressed concerns about using the Close Request feature within CoAware as it takes some control over a partner's phone and may disrupt their on-going activities. This, again, could create further tension between partners. Instead, participants felt that solutions that alert others of what they may want to change in their own behavior, rather than take control, would be more acceptable. Thus, when designing apps for communication between devices, it is important to carefully consider how much control one should have over another person's device.

Notification Strategies: Participants found pop-up notifications to be distracting and somewhat overbearing. Thus, I suggest that applications like CoAware use standard notification mechanisms that are already found on smartphones. Pop-ups notifications can be distracting and the forced change in activity (e.g., switching from a game to notification UI) could create new frustrations.

Determining whether the phone is in use: Sometimes a phone may remain active although the user may not be engaged with it. This means that usage information provided to one's partner may not be accurate. One

possibility could be to rely on information about the user's on-screen taps in combination with information about the running apps to determine usage history.

Study 1 of Phase 1 provided insights and direction for my design work with CoAware and helped lead to the aforementioned design suggestions. Its results also moved beyond prior literature (e.g., [69]) to allow me to more deeply understand when, where, and during what activities a system like CoAware would potentially be used in real-world situations. This can help guide future studies that want to test applications similar to CoAware to know when, where, and how such testing should be done. One could also imagine using Study 1's data on locations and context to think about ways to further refine applications such as CoAware. For example, users could be given options to customize applications so that they are able to choose what types of information they are comfortable revealing to their partner based on location, time, and activity. Such information could also be inferred by applications and then adjusted as needed by users.

I also recognize that there is a darker side to applications like CoAware and designers should be cautious in this regard. The challenge with apps that track or share mobile device usage between partners is that they can potentially alter relationship dynamics, given an increased access to information [22]. This could create issues around trust or control between partners. While my results did not reveal such concerns, they are most certainly possible. Further research is required to understand partners information sharing behaviour with others and its impact on their relationship. I also acknowledge that apps with features like CoAware could be seen as being highly problematic for relationships that contain domestic abuse or family violence [23]. As apps like CoAware enable access to information on partners' devices, this could lead to the system being misused (e.g., coercing to share information constantly, surveilling one's partner) and create anxiety and tensions within a relationship. There are no easy solutions for such types of situations. CoAware could, for example, ask users for details about their relationship satisfaction before making features available to them. Yet partners in an abusive relationship could easily answer untruthfully. Apps could track couples' information sharing behaviours and provide warnings if acts that appear to resemble surveillance occur, or features could be turned off based on certain negative behaviours. However, this may, again, not be a complete solution and may be hard to detect. As such, designers need to be cautious to think about the possible negative consequences of apps with features similar to CoAware.

I will now move into my discussion on Phase 2 as well as my design

recommendations after the development of my agent-based app.

My results suggest that the agent-based mediation was successful in reducing smartphone usage. Over the course of the study participants mentioned they changed their smartphone usage behavior in comparison to before. Their smartphone usage behavior differed in reducing their usage at meal times, keeping their smartphones a hand's length away, and finding times to put their smartphone away and instead interact with their partner. Additionally, the smartphone agent made participants more inclined to start focusing on tasks, such as work, and connecting with each other. The audio feedback helped couples to change what they were doing immediately as they would get startled from the notification. Not only could the agent contribute in this way, but as the agent voiced messages out loud, people could feel embarrassed when the notification would be spoken thus leading them to not use their phone as much.

The smartphone agent also acted as a mediating support of communication between couples and improved co-located interactions. By acting as a intermediary channel between co-located individuals, they felt as though they could talk more freely with one another. Thus, invoking more conversations because the agent would hypothetically be the one initiating the conversation and not the couples themselves, as the agent would voice out the message out loud. Hence, helping to reduce any complaints that would come from their partner for smartphone overuse. Furthermore, as the notifications are preset messages, it removes any complications that may occur in normal messaging, such as an unwanted tone of a message. In addition, the agent was perceived as a third person or another social entity in the interaction between two co-located individuals. To encore, all these aspects were observed from a mediating agent that simulated playing a third party in exchanging information between couples. Thus, it would be interesting to see how future research can leverage more features for the smartphone agent to further develop this mediating aspect.

I do also acknowledge that there are potential negatives to having a smartphone agent involved in conversations between couples. Two participants mentioned they thought the third party agent was invading their relationship at times and would rather just use normal text messaging. The participants did clarify however, this was due to them having a close knit relationship with one another and don't believe having the smartphone agent is necessary for them.

From my study results, I offer the following design recommendations for future researchers:

Smartphone Agent Behavior Participants expressed that the smart-

phone agent acted as a social entity in their conversation and mimicked human capabilities. Designers should consider leveraging agents for other domains (e.g., group chat messaging), knowing that people view it as a another social entity in the communication between one another. Also, the agent-based app enticed users to focus more on tasks and each other, in comparison to the text-based. Designers can use the agent to convey more important messages (e.g., tasks to be done at work), which is a result of the agent-based app enticing users to feel more inclined to read/listen to them in contrast to a simple notification seen in many existing apps.

Enable Awareness Participants mentioned that being aware of what each other were doing contributed to how they interacted while co-located. Most of this awareness stemmed from checking the usage statistics of the app. Developers should consider this feature to be integrated in future renditions of this app or other smartphone information sharing apps, to enhance conversation amongst co-located individuals. Additionally, this awareness factor also played a part in one individual's mindset as they were more attentionally aware of what they were doing on their smartphone at all times. Thus, designers could use this aspect in apps that aim to reduce smartphone usage for individuals.

Assisting in Time Management Participants specified the apps assisted them in their own time management. Future OS or applications could be designed to help users manage their time better. For example, connecting this app with a calendar app could allow for further integration's of providing more valuable notifications. Per say, if an event is schedule with family members at a certain time and I am still using my phone, I could receive a notification letting me know that I have been on my phone for too long and reminding me to go to the event. Also, the time management aspect could be useful for study tracking apps, where users are confined to only use their phone for a certain period of time until the app triggers a notification to remind them to stop.

Help Mediating Conversations/Communication Participants mentioned that both sets of apps (text and agent-based) contributed to starting and mediating conversation. Designers could leverage these aspects in various apps (e.g., dating or messaging apps). The app could use an AI based system to see how much communication I have with my family members and then remind me to connect with people if I haven't talked to them in a long time. The app could even offer helpful insights to further mediate the conversation by coming up with preset messages to send knowing that from my study results these helped mediate the conversation between co-located individuals. Furthermore, initiating conversations can be oftentimes

difficult and designers could leverage this app aspect to give helpful starting conversation starters.

Chapter 9

Limitations and Future Work

I will first go over limitations and future work of the first phase of my study.

My crowdsourced survey has some inherent limitations. Since I used AMT, my participant's demographics were determined by the demographics (USA and India) of the ATM. With a larger sample and with participants from more cultures, it is possible to investigate how people's perceptions of co-located phone usage differ between cultures. It would also be interesting to conduct an in-person study with interviews to determine whether the results differ from those that have been obtained from crowdsourced study. In an in-person study, I would be able to see how people use the design for real-life situations which may not completely match the tasks in my study and essential to ground and guide the developments of CoAware. This would further help me cover ethical aspects of smartphone activity-awareness between couples which might be missed in my online survey. The challenges and potential problems that may arise with an increased awareness, especially in abusive and problematic relationships, needs further investigation. I believe such future research would provide me with important insights into the scope and impact (both positive and negative) of using CoAware and similar technological solutions in sensitive family situations.

I concentrated on partners' co-located smartphone activity awareness and investigated their opinions on CoAware. However, I envision extending my approach with CoAware to other relationship types, such as between parents and children, where the parent could use CoAware to monitor and control the child's smartphone activities. This would require an in-depth study of parent-children relationships and the consideration of many other aspects, such as the diversity of house rules, family traditions of raising children, child age, and the educational backgrounds of parents.

We do acknowledge that WiFi direct poses issues such as eavesdropping as a user with an Android smartphone can connect to another Android smartphone through WiFi direct. For instance, a user located within 100m using the same app (i.e., CoAware) can connect their phones and listen to the data being sent. Thus, using other solutions such as, for example,

Bluetooth could be a potential solution to be used instead of using WiFi direct.

With my initial encouraging results and reactions, I plan to further develop CoAware and to perform a longitudinal study with a full-fledged version to examine its effect on sustained behavior change among people. Additionally, CoAware inspires the design of context-aware smartphones where the solution can trigger notifications based on preset rules based on locations and any surrounding people to reduce the smartphone use of co-located persons.

Next, I move onto limitations and future work of the second phase of my study.

My study has some inherent limitations, which I discuss below. I conducted the study with 12 couples from Canada which may influence the smartphone usage patterns I saw. Depending on what societal background people come from, they can either be more inclined to use their smartphones when around each other or have strict rules in place to reduce this behavior. Consequently, it would be interesting to run a further study to see the results with a larger and more diverse set of couples with different ages, backgrounds, and relationship lengths. As with any research study taking place over the past couple of years, Covid-19 could play a role in participants responses. When everything returns back to normal, it would be interesting to see whether the results would remain the same.

I used distance-based co-location for this study, where I considered couples to be co-located when they are within 100 metres of one another. However, other forms of co-location could be explored. For example, two users can be considered as co-located when they are within their view or sight. I need advanced vision-based solutions on smartphones (e.g., capturing 360-degree views) to implement such co-location - which can be a potential future work. Virtual Private Networks (VPN) can also be exploited in this system as individuals may be able to disguise their location and be someone they are not. In other words, the app sees them as being co-located when they are not.

Very little was known about smartphone agents exchanging messages and notifications between people. Thus, I envision further developing my agent to include more features. Developing an AI-based agent that allows customizable parameters to be set to the AI to accurately detect when to send messages to the users could also be added. Interacting with the smartphone agent through voice would be a potential extension for the future. Another study could be conducted to determine the best way to send notifications through an agent, such as breakpoint-based notification strategies where no-

tifications are only sent by identifying breakpoints at more opportune times [71]. It would be interesting to allow users to send custom messages and see how it influences communications between them. Additionally, including gamification techniques on the apps can be a potential venue for future research. For instance, we can investigate reward-based solutions where users can get some redeemable points once they do not use the smartphones for a certain amount of time.

For Study 3, I mainly focused on qualitative data. However, further studies can be conducted focusing on collecting quantitative data. It would be interesting to see how the app affected participants' smartphone usage in pre/post-study conditions. We can possibly run studies for a longer time where we spend one week collecting users' smartphone usage data without any agent or text-based app (pre-condition). Then one of the apps (i.e., agent or text) can be used for one week to see participants smartphone usage patterns (post-study). Having such data would allow us to directly compare users' smartphone usage.

Chapter 10

Conclusion

In this thesis, I aimed to design a solution to improve co-located communication between partners. This was done by splitting my work into two phases.

The first phase consisted of conducting an initial crowd-sourced study (via AMT) to investigate people's smartphone usage, rules, trust and privacy concerns, and activity awareness when they use smartphones in the presence of their partner. Results showed that people often use smartphones while co-located with the partner, which sometimes leads to anger and frustration, and in addition partner's tend to be untruthful of what app they are using at sometimes, thus being unaware of what each other are doing.

This motivated me to design a smartphone app, Co-located Awareness (CoAware), intended for sharing smartphone usage information between co-located partners. CoAware was designed to share users' smartphone usage information such as the number of times an app has been launched, the duration it has been used for, and the time it was initially opened. I continued with an in-lab study with couples who explored and provided feedback on the features offered by CoAware. Results showed that low-level information was seen to be unnecessary and too much in comparison to the high-level information that was seen to be useful. Additionally, Co-Aware didn't fully grasp the communication facilitation aspect that was desired to be seen between couples.

This first phase led us with valuable information to develop on for my second phase. The main two changes focused around only sharing app name between partners' and developing a brand new smartphone agent-based app that could be compared to a text-based application that technically was an updated version of Co-Aware. The lone study of Phase 2 starting by designing these two versions of the apps (text-based and agent-based) and then conducting a user study with these. The design of the two smartphone apps were as follows: (a) an agent-based app that exchanges smartphone usage activities (e.g., app name, app usage duration) among couples while mimicking a virtual agent presenting the information to them. The agent was represented with a name, Anna, an avatar, allowing her to leverage

voice modality to send messages and notifications to partners via audio, and (b) a text-based app where a person can access and exchange the same features manually. The text-based approach involves no facilitator or social entity intervening in conversation between individuals. This approach is tailored towards partner-to-partner communication via standard text. The agent-based approach involves a smartphone agent (i.e., an app) designed to facilitate conversation between individuals. More specifically, I designed the app simulating an agent playing a human role in exchanging information between couples. Afterwards,I conducted a between-subject design study, exploring the effects of agent mediation on communication dynamics around co-located smartphone usage and compared the results to the text-based approach. Results revealed that the agent is beneficial in promoting co-located interactions by being a valuable support in communication requests between individuals

Finally, I discussed design guidelines, limitations and future work ideas in this co-located communication space. The main design guidelines I focused on for my first phase were ensuring personal digital space between individuals, the level of access granted for sharing, notification strategies, and determining whether the user's phone was in use. For the second phase the main design guidelines were insights into the smartphone agent behavior, the app enabling awareness of what their partner was doing, assisting them in time management throughout the day, and helping mediating conversations between partners. As for the limitations it would be interesting to see if results would change pre/post Covid. In addition, it would be interesting to see whether my findings were influenced by the participants age, background, and relationship length. Building towards the future, interacting with the smartphone agent through voice would be a stepping stone to this product to enhance the "agent" based aspect of the app. My thesis work on my smartphone agent can be the first step for researchers to build upon to further influence the communication dynamics in co-located individuals.

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