LOCATION AWARENESS: EXPLORING SOCIAL COORDINATION

by

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DALHOUSIE UNIVERSITY
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Abstract

Mobile location-aware devices are poised to influence our social experiences. It is important that we explore how these devices influence social behaviours and communication in order to understand their impact and realize their full potential. This thesis presents two complementary field simulations exploring the use of a mobile location-aware device to facilitate rendezvous activities.

The results of the first study revealed key differences in communication patterns and behaviours that are directly related to the information that each medium can effectively convey. The results of the second study revealed the importance of maintaining a visual awareness of the relative position between a user, their partner and/or target. We observed that participants would continually refine the map increasing region specific detail as the proximity between them and a partner or target location decreased. The results of both studies provide insight into design implications for future location-aware devices to support social coordination.

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Thank you Mom and Dad, without your love, support and encouragement I never dreamed I could have made it this far. Kori, thank you for not only being my supervisor but a friend. Your input and direction was invaluable. Teresa, thank you for your love and encouragement, you always know how to make me smile. Kirstie, without your support, assistance and insight I never would have been able to pull together my studies. Mike, Ritchie and Vicki, thank you for volunteering to be my study wizards. Without your assistance I would not have been able to conduct my research. Finally, thank you to all the members of the Edge Lab for your support and constant feedback on my work at every stage.

Chapter One: Introduction

1.1 MOTIVATION

Mobile devices such as cellular telephones and handheld computers are becoming increasingly pervasive in our culture and society. For many, these mobile devices are essential technologies that help facilitate their social interactions. The size and form of mobile devices allow them to accompany us throughout our daily activities where our interactions, as well as the environment and people around us, change frequently. Cellular telephones and handheld computers, once separate devices, are merging into a single platform as can be seen with today's current iteration of smartphones (e.g., Blackberry, and Audiovox SMT5600). These smartphones integrate mobile communication with lightweight computation and provide wireless connectivity using 802.11 and Bluetooth. Bluetooth and 802.11 enable a smartphone to connect with wireless networks and other independent technologies (e.g., a global positioning system (GPS) receiver, a desktop computer, and other smartphones). Harnessing information from many sources and combining it creates exciting new opportunities for applications and expands the usefulness of our independent mobile devices by combining their benefits. For example, combining GPS and wireless connectivity using a smartphone opens opportunities for smartphone applications to facilitate social coordination. GPS can provide location information to the smartphone that can be annotated on a virtual map and displayed on the screen for the user. The location of this smartphone can then be communicated wirelessly to other smartphone users within the user's social group, providing everyone within the social group an awareness of each others' locations. The location information

can then be used to facilitate coordinating activities, such as meeting up at the bar later in the evening for a drink.

The use of location awareness information on mobile devices has been shown to be useful for social engagement as has been seen with the research of Griswold *et al*. using ActiveCampus [22] and with the popularity of Dodgeball.com [15] (a commercial mobile social application). Depending on usage, availability of input techniques, and the task to be completed, location information can be presented, interpreted, and used in a variety of ways. Colbert [10] showed that mobile telephones were the preferred communication medium for people during a rendezvous. However, the exchange of contextual information such as location can be difficult to convey accurately through dialog. The verbal exchange of location, instructions, and intentions between coordinating people can be ambiguous, misinterpreted, and misunderstood. As mobile telephony hardware evolves, location-aware applications can be developed to augment verbal communication to facilitate the exchange and understanding of location.

Common methods for presenting location information include a textual description (i.e., "at the gym") or a map annotated with location indicators. However, mobile devices are extremely constrained in terms of how much information they can display and the complexity of the presentation. It is critical that effective use is made of the available display space, showing only relevant information, appropriately presented, and filtering out information irrelevant to the current task. Equally constrained by device size and mobility is interaction with the mobile device. A small screen has small input widgets that can be difficult to select, particularly given a high level of mobility. For example, imagine

rushing across campus to a meeting for which you are late and that is located in an unfamiliar location. It would be difficult to interact with your mobile telephone, selecting widgets and navigating menus and still be aware of your surroundings.

1.2 Overview of Research

This research was inspired by previous research by Colbert [9-12] who suspected that the use of a location-aware service could be used to facilitate rendezvous activities. A literature review of prior work in ubiquitous and pervasive computing revealed that the use of location awareness for social activities is an active area of research with little investigation of rendezvousing. This thesis examines the usage of a mobile location awareness device during social coordination, specifically a rendezvous. Mobile technologies can be used to provide users with an awareness of their location and that of others, but it is unclear how an awareness of location will influence coordination behaviours. Information need and usage is examined to identify common aspects of location and behaviour that can be automated (either directly or with user-guidance) to reduce the need for user interaction and make effective use of limited display space.

The results of this research will aid in the development of location-aware services for mobile devices used to facilitate social coordination and inform future social coordination studies using location-aware technologies.

1.3 Research Process

To explore the use of location awareness information during a rendezvous, two studies were devised. The first study was an exploratory field simulation to broadly identify how

technology impacts our behaviour and decision making during a rendezvous. Pairs of participants were observed completing three realistic rendezvous scenarios for one of three technology conditions: using a mobile telephone, a location-aware handheld or both a mobile telephone and location-aware handheld. The results of this first study identified the focus for a second study. The second study was a field simulation targeting information need and granularity for a location-aware map application. Participants were observed completing three realistic rendezvous scenarios using a location-aware handheld with a scripted partner.

1.4 ORGANIZATIONAL OVERVIEW

This thesis is organized into six chapters. Chapter 2 introduces pertinent background literature in the topics of ubiquitous and pervasive computing. Chapter 3 gives an overview of the first exploratory field simulation and provides a detailed discussion of the findings. Chapter 4 gives an overview of a second, more focused, field simulation and provides a discussion of the findings. Chapter 5 outlines design implications for future mobile location-aware applications used to facilitate social coordination. Finally, in Chapter 6 the conclusions from both studies are revisited and future work is discussed.

Chapter Two: Related Literature

This thesis is based on previous research in human-computer interaction, ubiquitous, and pervasive computing. The focus is on rendezvous activity, location awareness and location disclosure.

2.1 RENDEZVOUS

A rendezvous is the social activity of people meeting at a predetermined location and time. Group behaviours and communications related to rendezvous have been explored extensively by Colbert [9-12] through detailed diary studies. Colbert comments on the importance of conducting user-centered research to identify the effects of location awareness on rendezvous behaviour [11]. Colbert's work illustrates common rendezvous behaviours, scenarios, and various challenges that frequently arise when two or more people attempt to rendezvous. The rendezvous process is dynamic in nature. While meetings often occur as originally planned, some are problematic and may be delayed, restructured, or cancelled, resulting in lost opportunity and stress [11]. Colbert observed that 48% of rendezvous are problematic and do not occur as originally planned [11]. He suggests that a location-aware application could enhance rendezvous performance, addressing many of the problematic aspects.

In 2002, Colbert reported the results of a follow-up investigation into technology to support rendezvousing (mobile telephones, text messaging, email, and voicemail) and observed that mobile telephones were the preferred method of communication [10]. Other work by Ito and Okabe [28] investigated how mobile communication can alter

rendezvous behaviour. For example, rather than agreeing on a landmark and specific time to meet, mobile users can initially agree upon a general time and place and exchange several messages to further refine the rendezvous location and time, finally terminating in an eventual meeting [28]. However, Colbert has observed that communication during a rendezvous is perceived to be less socially acceptable, more frustrating and a cause of greater disruption when compared to communication prior to a rendezvous [12].

2.2 LOCATION AWARENESS

Location-awareness systems have come a long way since Active Badge [45], one of the first automated location systems. Active Badge was designed specifically for workers in an office environment. An Active Badge worn by office workers was detected by a sensor network in their work environment providing automated location information. Since Active Badge, location awareness has been explored by a number of researchers for a variety of activities including gaming [5, 6, 8, 18], support for communication and collaboration among distributed groups [22, 43], and support for awareness and collaboration among proximal groups [25].

Location-aware devices can provide absolute or relative location information. The representation of location information is conventionally separated into two models [7]: symbolic and geometric. A symbolic representation of location is usually achieved through abstract imagery while a geometric representation is based on a coordinate system. The Hummingbird, an *Inter-Personal Awareness Device* [25] is an example of technology that provides relative or proximal location awareness for users within a close physical vicinity. For example, when one Hummingbird comes within the vicinity of

another, it hums, indicating another Hummingbird is nearby. While beneficial in some situations, relative location awareness can sometimes be insufficient for people to find one another [25].

Several applications that have explored absolute location awareness include ActiveCampus [22] and Pousman *et al.*'s location-aware event planner [17, 43]. These systems provided their users with an awareness of their and other members' locations. The devices also provide an active communication channel through text messaging. ActiveCampus provides additional services such as ActiveClass [21] used to encourage participation between students and professors during lectures. Pousman *et al*'s location-aware event planner [43] allowed for spontaneous and planned scheduling of events. Events at a specific location could be annotated on a map.

ActiveCampus and Pousman *et al*.'s location-aware event planner applications have been field tested in situations that are reminiscent of rendezvousing. The combination of location awareness and a communication channel provides the ability to actively initiate a rendezvous with a partner. Griswold describes the situation of a student seeing one of her friends is nearby and messaging him to suggest that they go for lunch [22]. Although applicable to rendezvousing, the focus of this previous research was on the design and evaluation [17, 43], and general use [22] of the technology.

A more abstract representation of location awareness information can be seen in Marmasse *et al*.'s work on WatchMe [38], a contextually aware personal communication device (in the form of a watch). Contextual information is extracted by comparing user

movements to previously recorded patterns terminating at user-defined locations. The context of the user's location is then displayed in a descriptive or symbolic manner, such as “gym”, not in absolute coordinates or as annotations on a map. The device was proposed to facilitate communication within an person’s inner circle (e.g., intimate friends and family members), not the general public.

2.3 LOCATION DISCOURSE

Patil and Lai explored users’ preference for balancing awareness and privacy using an application called MySpace [42]. Their results revealed that users consider location to be “the most sensitive component of awareness” [42]. However, despite the sensitive nature of location, users were willing to disclose their location to work colleagues while working. However, disclosing one’s location to colleagues during office hours was seen as advantageous, and helped to facilitate the completion of work tasks. Their willingness to disclose their location to fellow colleagues did not extend beyond office hours. Similarly, during Griswold *et al*.’s study of ActiveCampus [22], they showed that location disclosure in social situations can be equally beneficial for spontaneous social engagement.

Although location information as proposed by Colbert [11] can be useful for rendezvous, Hong *et al*. [26] has shown that limiting our disclosure and privacy management involves a value tradeoff. Managing privacy requires that many social, organizational and technological factors must be taken into consideration during the design of a location system. A study of users’ privacy concerns by Barkhuus [3] has shown that if users have a perceived usefulness of the location service they are less concerned about their location

being tracked and more likely to disclose their location. However, there are still times in our day to day life when we would prefer to be anonymous or unaccountable [2]. It is important for a location service to support personal or solitary activities (e.g., personal or alone time) in addition to social activities when disclosing location information may not be desirable or useful. Nardi *et al*. [40] suggest that mobile communications facilitate ambiguity and plausible deniability because of the physical separation mobility affords. Mobile users can avoid entering a conversation when their telephone rings because of the separation between them and the requestor. Typically, ignoring a face to face request for a conversation would be considered rude.

Consolvo *et al*. [13] explored social considerations that influence a user's willingness to disclose their location. This work revealed that the relationship between the location requestor and location provider has the greatest influence on the provider's willingness to disclose their location. For example, participants were more willing to disclose their location to a significant other/spouse as opposed to a co-worker or a manager. This is a significant finding because Colbert observed that the majority of rendezvous (86%) occurred between immediate family or close friends [11]. This finding confirms a previous finding by Lederer [34] who showed that a user's willingness to disclose their location or activity was primarily based on the relationship or identity of the requestor. Marmasse had similar findings suggesting that people may be more comfortable sharing location information with their "inner circle" [38]. Our willingness to disclose our location is additionally based on location specific social networks [29] as seen earlier with Patil and Lai [42] who observed office workers. For example, with a location specific network when we are at a specific location (e.g., school, or work) we are often

willing to disclose our location to others within the community. We are willing to do so because we anticipate a benefit to our, or the community's activities. However, our willingness to disclose our location does not extend beyond the location of that community of people.

The results of Consolvo *et al*. [13] also show that location disclosure is often dependent on what the provider perceives the requester needs. For example, if I am currently out of the county attending a conference and a friend from home inquires about my current location I might tell them I am in Germany rather than my specific civic address. The friend is most likely inquiring about my location to see if I am available to meet, so telling them I am in Germany should provide enough information for them to infer that I am not available. Providing the civic address may give the same effect, but contains greater superfluous detail. Weilenmann and Leuchovius [47] had a similar finding as Consolvo *et al*. [13] that states our description of location is commonly based on terminology that is familiar to both the provider and requester and based on previous experiences between the two. Weilenmann and Leuchovius describe a form of positioning that they call "where-we-met-last-time-formulations", where location isn't directly revealed (e.g., "City Hall") but revealed indirectly based on previous experiences of the two communicating persons. For example, if two friends commonly frequent a local diner for lunch, they may refer to the diner as "the regular place" rather than its name.

As we have seen, location is highly malleable and often extends beyond coordinates and place [32]. Harrison and Dourish show in their earlier work [23] that bare geographic locations (e.g., latitude and longitude) although highly accurate are less expressive and

infused with less meaning than a place name. Weilenmann [46] has shown that location can be used to disclose a person's current activity or availability. For example, someone sitting at home watching TV would suggest availability whereas someone attending a class lecture would indicate unavailability. Iachello *et al*. [27] observed that when requested to disclose their location, users were equally likely to disclose their activity (48% [27]) instead of a place. These findings suggest that activity plays a significant role in awareness.

Reno [27], a location disclosure application developed by Intel, focuses on the importance of user privacy and the relationship between the user and the location requestor. Physical locations are labeled using place names specified by a user that can be forwarded to a location requestor. When a user discloses their location, a technique such as BeaconPrint [24] is used to apply previously defined place names to the user's current location. An appropriate label is selected by the user and then disclosed to a location requestor.

2.4 VISUALIZATION FOR LOCATION AWARENESS

Mobile map based services (i.e., location-aware maps) benefit users because they provide an awareness of the user's location [41]. The user's location is annotated on the virtual map to represent their actual location in the physical world. Used in a social context, a mobile location-aware map can provide the location of many users [22] as seen with the ActiveCampus application. However, the small display space of mobile devices (particularly mobile telephones) imposes limitations on the presentation and scale of location and map information. For example, it can be difficult for users to discern the distances between numerous location markers shown on a small screen [43]. If the

relative distance between participants is important for coordination it is possible to use visualization techniques to augment the map to better illustrate relative distance and position.

Interaction techniques such as the zoom-able user interface (ZUI) used in Google Maps [36] and ZoomZone [44] (specifically for the mobile telephone), allow users to focus on a specific map region, zooming in or out to gain less or more map detail. ZoomZone [44] partitions the information space (i.e., the map) into regions that correspond to the keypad on a mobile device. Selecting a key specifies a region to zoom in upon. Zooming techniques facilitate feature identification [35] (e.g., buildings and roads) by allowing users to refine their map view to obtain greater detail.

Non-ZUI techniques could include fisheye views [19] and the Halo [4] visualization technique. Fisheye views [19] condense the areas of non-interest into the outer region of the interface. Since this technique distorts the information space, it may be difficult for users to understand the relative distances between participants. The Halo [4] technique does not distort the information space but provides a visual clue (in the form of a partial ring) showing off-screen locations and the relative distance to the location. The relative distance to off-screen locations is discernable by the arc and size of the visible portion of the ring.

Chapter Three: Location Awareness and Rendezvous Behaviour

The material for this chapter is drawn from a previously published article by the author entitled “Rendezvousing with location-aware devices: Enhancing social coordination” in the journal *Interacting with Computers* [14]. This work was done in collaboration with Kirstie Hawkey.

3.1 INTRODUCTION

The methodological challenges of conducting mobile research in the field are well known [1]. Abowd and Mynatt [1] stress the importance of in-context usage of ubiquitous systems to effectively evaluate them. It is believed that it is important to provide sufficient details of our methodological approaches so that the validity of this work can be accurately assessed and so that others can learn from the approaches taken. Where appropriate, reflection is made upon the impact that our study design had on our ability to observe and analyze the effect of location awareness on participants’ ability to rendezvous.

3.2 STUDY DESIGN

An experimental simulation was conducted in the field to explore how technology impacts social coordination (i.e., rendezvous). Participants took part in one of three separate technology conditions: mobile telephone; location-aware handheld computer; or both mobile telephone and location-aware handheld computer. Three distinct rendezvous scenarios were simulated to ensure that a range of behaviours could be observed.

The use of location-aware software is not limited to a particular setting and is applicable to a range of social activities. It was therefore important to observe usage in a realistic setting [1], despite the fact that experimental precision and control would be sacrificed [31]. An urban environment was chosen to provide realistic observations; however, the dynamic nature of the environment (e.g., amount of pedestrian/vehicle traffic, construction and signal lights) meant that environmental conditions were not constant across pairs of participants. As a result, quantitative measures, such as the time it took for participants to rendezvous, were not directly comparable.

3.3 PARTICIPANTS AND SETTING

Forty-eight participants (28 male and 20 female) ranging in age from 18 to 56 (mean 26) took part in this study. Recruitment notices were sent to Dalhousie University faculty, staff, and students. Participants provided informed consent (see Appendix A) and were compensated $10 for participation in the study. Some of the participants signed up as pairs (often with family or friends external to the university community), and therefore had a previous relationship with their partner. Other participants signed up individually and were assigned a partner who, in most cases, was unknown to them. Of the groups, 4 had no prior relationship with their partner, 1 group were acquaintances, 11 were friends, 2 were family members, 5 were a spouse or a significant other and 1 group indicated their relationship as “Other” and was not clarified.

The mobile telephone experience of the participants was varied. Twenty-nine participants indicated frequent mobile telephone use (at least a couple times a week), while the remaining nineteen indicated infrequent use. The majority of the participants were

inexperienced with handheld technology with thirty-five participants indicating that they had never used a handheld device, four indicating infrequent use (at most a couple of times a month), and the remaining nine indicated that they use a handheld device frequently (at least a couple times a week).

Most of our participants were familiar with the study area. Twenty-eight participants indicated that they shop/walk there frequently (one or more times a week), sixteen indicated that they shop/walk there monthly, and the remaining four indicated that they rarely or never shop/walk in this area.

The study took place in August 2004, within a four block radius encompassing the Spring Garden Road district in downtown Halifax, Canada. This area of the city is a busy shopping district with numerous shops, prominent landmarks, and pedestrian/vehicle traffic.

There were several social considerations associated with conducting the study in a busy downtown area. Participants had to dodge pedestrians as they navigated using their map or handheld device. Curious passers-by and shop owners sometimes stopped to watch, or to inquire what was going on. Encounters also occurred with people on the street such as buskers and panhandlers. Being in a public place also increased the potential for embarrassment and feelings of self-consciousness on the part of the participants, particularly because they were equipped with voice recorders and were trailed by researchers.

Weather conditions were also an issue throughout the study. Participants were rescheduled when it rained because of the possible damage to the study materials and technology. Wind and sun also affected the study. Wind made it difficult for participants and researchers to handle paper forms. Bright sunlight made it difficult at times to view the handheld computer's display because of glare. Other environmental factors also created problems, such as when tree sap dripped on the equipment while in the park used for pre- and post-session questionnaires and interviews.

Running the study in the field also meant that the researchers did not have access to a "home base" which impacted study procedures. Equipment and paperwork had to be carried throughout the experiment. There were no power outlets, requiring careful management of battery power during long study days. Experimental conditions were assigned, in part, based on the level of battery power available for the various devices. Park benches were used for interviews and clipboards were use to manage paperwork.

3.4 TECHNOLOGY CONDITIONS

3.4.1 Mobile telephone

The mobile telephone condition was intended to be the control group from which we could examine how mobile location-aware technology differed from previously identified rendezvousing behaviours (based on Colbert's earlier work [10, 11]). In the mobile telephone condition, participants were provided with a mobile telephone programmed with their partner's telephone number. Each participant was also given a laminated paper map of the area (identical to the map provided on the handheld computer used in the other

Figure 2. Interface for the location-aware application running on a handheld computer; (a) represents the partner's location, (b) represents the participant's location, and (c) represents the rendezvous location.

Figure 1. The laminated paper map provided to participants in the mobile telephone condition.

conditions). The map showed the outline of most buildings in the experiment area (see Figure 1) without names. The participants in this condition were the only ones provided with a paper map.

3.4.2 Location-aware handheld computer

In the location-aware handheld computer condition, participants were provided with an HP iPAQ h4155 handheld computer. Each handheld computer ran a custom location-aware map application that enabled participants to view a street map of the experiment area annotated with the participants' locations and rendezvous location (see Figure 2). Each participant was represented by a different coloured dot. Approximately $1/6^{th}$ of the map was visible at a time and participants panned the display to navigate the map.

The map application also provided participants with an interface to negotiate a rendezvous location. To suggest a new rendezvous location, participants selected the rendezvous indicator (an "X" within a circle) and moved it to the desired location. The participant then selected the "ask" option from the rendezvous menu at the bottom of the screen. This caused a message to pop up on their partner's screen indicating that a rendezvous location had been requested. The partner then viewed the suggested rendezvous location and responded by accepting, rejecting or ignoring the request (through the rendezvous menu). The rendezvous indicator remained red until both participants agreed upon the location, at which point it turned green.

3.4.3 Mobile telephone and location-aware handheld computer

In the mobile telephone and location-aware handheld computer condition, participants were provided with both a mobile telephone and the handheld computer running the custom location-aware map application (as described in 3.4.2). The participants were told that they were free to use either technology at any time during the study.

3.5 Using Wizard of Oz to Provide the Illusion of Location Awareness

We initially envisioned the location-aware handheld computers being GPS-equipped and connected via a Wi-Fi/cellular network allowing for the automatic exchange of location information. Early on in our testing it became evident that using GPS to determine location on the handheld computers would be extremely challenging. For this study it was important that the location information be accurate and reliable.

GPS technology in “urban canyons” (i.e., the canyon effect created by a street or pedestrian path surrounded by buildings) [37] is inherently inaccurate and has the tendency to be intermittent. This is not an uncommon problem as other researchers have had similar problems using GPS in an urban environment [18]. Additionally, the Spring Garden Road district of Halifax at the time of this study did not have widespread publicly accessible Wi-Fi hotspots. Given these limitations, we developed a simple, effective and easy to implement Wizard of Oz approach to provide participants with the illusion of GPS and Wi-Fi/cellular connectivity.

The illusion of wireless connectivity and location awareness in our study was provided by two Wizards (see Figure 3). The Wizards were each equipped with a Bluetooth enabled handheld computer (similar to that of the participants) that ran a modified version of the

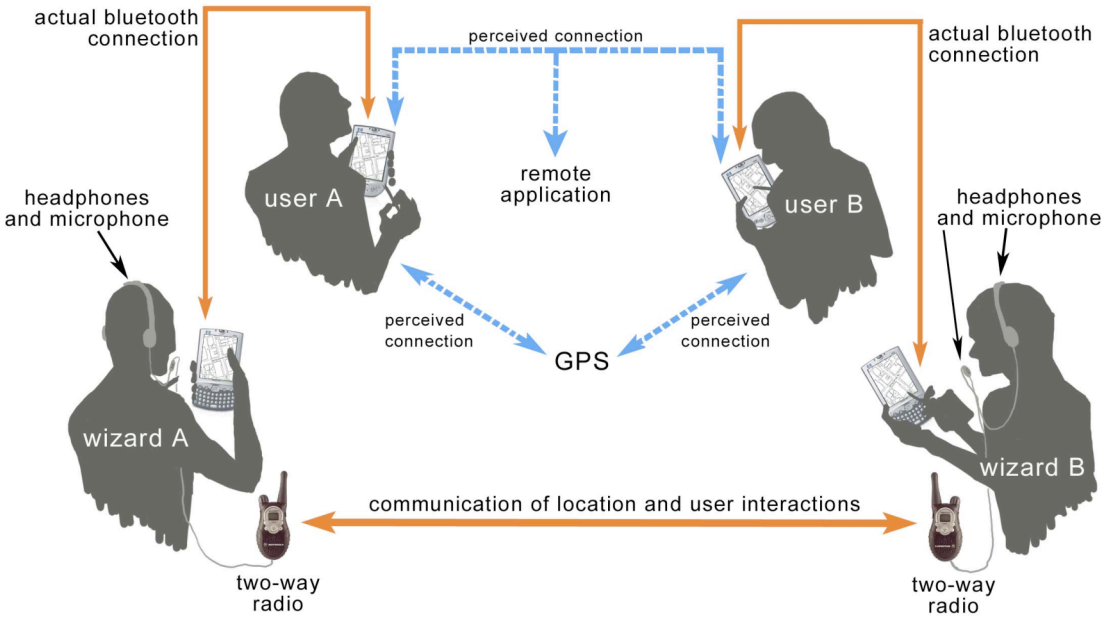


Figure 3. A Wizard of Oz technique was used to provide the illusion of location awareness to the participants.

custom location-aware map application. Each Wizard was assigned one participant to track and followed a short distance behind their participant for the entire session. A Bluetooth connection was established between the participant's handheld computer and their Wizard's handheld computer. This provided the Wizard with the ability to update the participant's handheld computer indirectly. The two Wizards themselves were in constant contact via 2-way radios, communicating location information of the participant they were following, along with any rendezvous requests or acknowledgements. Although this approach of self reported positioning may appear unreliable, it has been shown to be credible in previous research [5] and worked very effectively in our study. When the participants and Wizards were within sight of each other, the Wizards were able to accurately position both participants on the map. When out of sight, small inaccuracies in position caused by a lag in communication between the Wizards was not apparent to the participants as they could not physically see their partner's precise location.

3.6 EXPERIMENTAL PROCEDURE

At the beginning of each session, the researchers met the two participants in a small park located at the edge of the study area. Each participant was first asked to fill out a background questionnaire. Following this they were given an introduction to the technology they would be using in the study (a mobile telephone, a location-aware handheld computer, or both). To ensure that the participants were familiar with the devices, they were asked to complete a practice rendezvous task which required each participant to both request a rendezvous location (marked Start in Figure 4) and acknowledge their partner's request. In the case where participants used both the mobile telephone and the location-aware handheld computer, they were instructed how to use

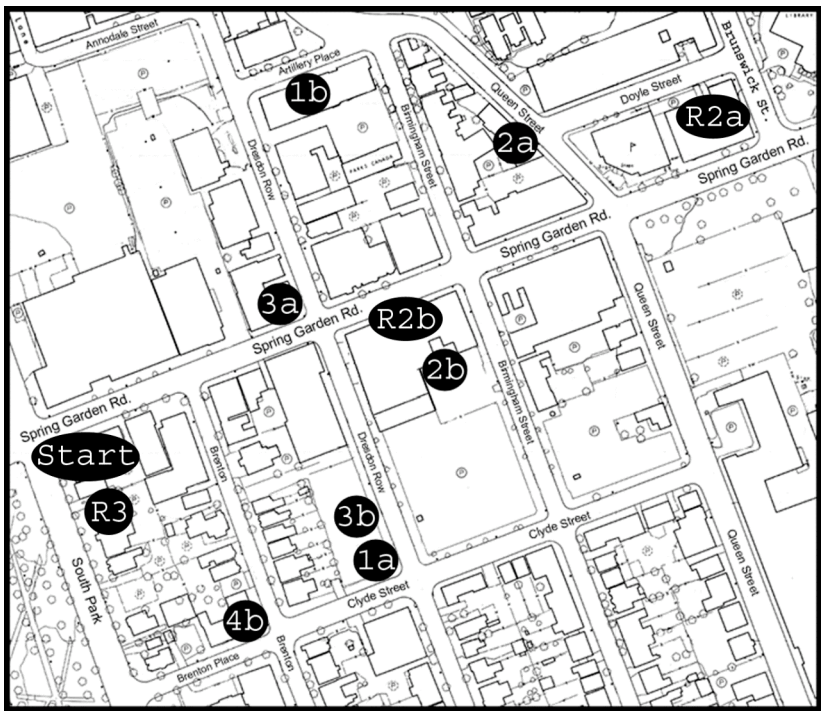


Figure 4. The complete map used by the participants: 1a - 3a and 1b - 3b represent the individual task locations for each partner (for task 1 - 3 respectively). 4b is the secondary task location where the participant who went to 3b was delayed. R2 and R3 represent the provided rendezvous locations. Start represents the initial starting location.

each device, but separately. After the rendezvous was agreed upon, the participants were instructed to proceed to the rendezvous location.

After the practice rendezvous, participants were informed they would be taking part in three different scenarios where they must meet up with their partner after completing individual tasks. These tasks were designed to separate the participants so that they could then rendezvous. The tasks were assigned to the participants individually, both verbally and on a task card that listed a business name and its civic address. Participants were unaware of their partner's task location unless they chose to communicate that information. Once the individual tasks were completed, the participants were required to negotiate a rendezvous location or meet up at a predefined rendezvous location. Figure 4

shows the map of the study area, annotated with the task and rendezvous locations. After completion of all three scenarios, the participants took part in a semi-structured interview with the researchers to gather additional information and discuss the social interactions exhibited in each scenario.

Given that the area where our study took place was a high traffic area (both in terms of pedestrians and vehicles) participants were instructed to not run, and to obey all local traffic laws for their safety and for that of the researchers and Wizards following them. We frequently had to remind participants of this during the scenarios. In one instance, a participant became completely separated from the observer after darting out into the street as a traffic light was changing. Connectivity issues with the Bluetooth devices occurred when participants were out of range of the Wizards, which meant that researchers sometimes had to interrupt sessions to reset the equipment. In two cases, the interference was significant enough that participants commented it affected their behaviour. These sessions were discarded and additional participants recruited.

3.7 RENDEZVOUS SCENARIOS

Three scenarios were drawn from the set of rendezvous behaviours identified by Colbert [10, 11] and modified to be appropriate for our experimental environment: (1) arranging a rendezvous while separated, (2) negotiating a new rendezvous when one partner is unresponsive and a previous rendezvous has already been negotiated, and (3) one partner is delayed while the other is waiting at the rendezvous location.

The unpredictability of the setting and the response of users to the activity patterns of the environment meant that the scenarios often did not occur precisely as planned. However, even when a scenario did not happen as planned, the participants ultimately did rendezvous, so we were able to observe a broad range of behaviours.

3.7.1 Scenario 1: Let's meet here

In this first scenario, participants were instructed that they would each be given a task to complete (located at 1a and 1b, Figure 4), after which they were to arrange a rendezvous location (either partner could initiate the rendezvous). After successfully negotiating the rendezvous they were instructed to proceed to the agreed rendezvous location. The goal of this scenario was to see if two distributed people could easily arrange and carry out a rendezvous. We observed how the participants negotiated the rendezvous, the location and nature of the rendezvous selected, how they made use of the technology provided (depending on the condition), and recorded any difficulties they encountered while completing the task.

3.7.2 Scenario 2: Why won't they respond?

In the second scenario, participants were asked to complete individual tasks (located at 2a and 2b, Figure 4) and then rendezvous at a pre-determined location (R2a, Figure 4). After completing their individual tasks, one participant was told that the rendezvous location had changed and was asked to proceed directly to the new location (R2b, Figure 4). The other participant was also told of the change and was instructed to communicate the change in location to their partner; however, we did not allow this communication to succeed. If the mobile telephone was used, the call was automatically forwarded to voice

mail. If the location-aware handheld computer was used, no acknowledgement was sent. The goal of this scenario was to observe what the requesting partner would do when their partner was unresponsive and a previous rendezvous had already been negotiated. We observed the behaviours of the participants, how they made use of the technology provided, where they chose to go to meet their partner, and recorded any difficulties they encountered while completing the task.

3.7.3 Scenario 3: Why are they late?

In the final scenario, participants were again asked to complete individual tasks (3a and 3b, Figure 4) and then rendezvous at a pre-determined location (R3, Figure 4). After completing their individual task (3b, Figure 4), one participant was told that they needed to complete an additional task (4b, Figure 4) before proceeding to the rendezvous location. The goal of this scenario was to force one partner to be late for the rendezvous and observe what both partners would do. We observed the behaviours of the waiting participant and the delayed participant, examining how they made use of the technology provided (depending on the condition), whether or not the waiting participant chose to stay at the rendezvous location, and recorded any difficulties encountered while completing the task.

3.8 Data Collection and Analysis

In order to capture the behaviours of the participants, a variety of data collection methods were employed. Data was collected via field notes, audio recordings, data logging, questionnaires, and semi-structured interviews. Pertinent data from these sources were aggregated into a single, linear narrative, enabling us to understand how participants

proceeded, given the device condition. The multiple data sources were invaluable as the quality of individual data measures was often low due to the difficulties of mobile data capture in an urban environment. Kellar *et al*. [30] provides further discussion about the challenges we encountered conducting mobile research in an urban setting.

3.8.1 Audio recording

Each participant was equipped with a digital voice recorder in order to create a record of all comments and conversations. The recordings were transcribed and pertinent comments and conversations were added to the linear narrative of the rendezvous.

Scenarios were piloted to measure audio quality and appropriate placement of recording equipment on participants. The quality of audio recordings was low due to background noise. When participants walked on crowded sidewalks, their recorders picked up third-party conversations. Environmental noises such as construction, tour bus commentaries, large trucks, and traffic were continuous and often drowned out the voice recordings. As both participants had microphones, sometimes what was missed on one recorder could be picked up on the other.

3.8.2 Field notes

Observing mobile participants in an urban setting made data collection difficult. Observers trailed participants so as not to influence their behaviour, but it was often hard to stay close to participants in crowded areas. This unconstrained mobility made it difficult to monitor interactions with materials and to interpret gaze (i.e., was the participant looking at the handheld computer or down the street).

Observers made field notes recording participants' actions and verbal comments. These observations provided context for the audio conversations recorded. Timing data was recorded, but since the scenarios were difficult to control, timings were highly variable. The timing data was primarily used to provide "landmarks" when integrating the various sources of data.

Coding sheets were created on the assumption that entering structured observations would be easier for recording observations while in motion. Pilot testing revealed that detailed observations were extremely difficult to capture on the street while trailing behind a participant and avoiding pedestrian and vehicle traffic. Observers were unable to count interactions (e.g. map glances) precisely, so coding sheets were reformulated to capture more qualitative user behaviours. These behaviours included the participant's level of confusion about their current and destination locations, and their patterns of map interaction. Ample room was included for free-form notes. To reduce the amount of paper to manage, coding sections were integrated with researcher scripts and checklists for each scenario.

Field notes taken while walking were often terse and messy, and therefore difficult to transcribe. Due to the difficulty of note taking while mobile, often the notes were made when the participants were stationary, which was not necessarily when something was observed. The field notes were also used to supplement participant comments on the audio recordings that were sometimes incomplete or misleading.

3.8.3 Data logging

All actions performed using the location-aware handheld computers were recorded. The logging allowed for a more concise analysis of the rendezvous locations negotiated and general interaction with the system. This data was also used to confirm user interactions that were noted by observers and to shed light on comments made during interviews.

3.8.4 Self-reported data

A demographics questionnaire was administered to gather background information on participants. Following each rendezvous scenario, a simple questionnaire was administered to determine users' perceptions pertaining to the rendezvous just completed. A post-session semi-structured interview was conducted to further probe the participants' rendezvousing experience. Questions were designed to identify participants' choices given the situations and how the available technology affected their actions.

3.9 RESULTS

This section presents the results and behavioural observations of the study as abstracted from the linear narratives. Despite the fact that participants' individual differences shaped their social coordination, common patterns were clearly evident. The behavioural data, as interpreted and presented in this section, provides important insights into how location-aware technology can impact social coordination. Common behaviours and issues observed for each rendezvous scenario, in each of the mobile device conditions, are characterized through narratives and associated discussion. All of the narratives represent real data collected in the study. In each case, a rendezvous occurred, although not always as originally planned.

3.9.1 Scenario 1: Let's meet here

In the first scenario, participants arranged a rendezvous location after completing individual tasks.

Condition 1: Mobile telephones. Using mobile telephones, all participants easily managed the coordination necessary to negotiate the rendezvous location. Table 1 demonstrates the typical communication exchange for participants in this condition. One striking pattern that was observed was the amount of phatic communication. Phatic communication

involves the exchange of "small talk" in order to establish a rapport with one another when initiating and ending a speaking relationship [33, 39]. This form of communication was observed in all conditions that used mobile telephones across all three scenarios. Although phatic communication can be used to enrich a conversation and give it a more personal feel (e.g., "Hey, how are you doing?"), it relies heavily on clichés and

Table 1. Amanda and Jason's illustrative narrative for Scenario 1 using the mobile telephone

Amanda and Jason each went off to perform their individual tasks. Amanda arrived first at her task location and picked up the mobile telephone to call Jason.
A: "Hey, how are you doing?"
J: "Hello, how are you?"
A: "Good, good. Where are you?"
J: "I am at John Allan's Cigar Emporium."
A: "Alright."
J: "Where are you?"
A: "I am down at Clyde and Dresden."
J: "You're down at Clyde and Dresden?"
A: "Hair Design Centre."
J: "What are you beside?"
A: "Across from the liquor store."
J: "Ok, I can be there. Do you want me to meet you?"
A: "I can meet you at Shoppers. Is that better?"
J: "Shoppers is fine."
A: "Ok, I'll meet you at Shoppers then."
J: "Shoppers, I can be there. Wait for me there."
A: "Ok. Bye."
J: "Ok. Bye."
Amanda and Jason headed to Shoppers Drug Mart and rendezvoused successfully.

superfluous conversation exchanges. As evident in our observations, phatic communication caused the conversations to be longer and more drawn out than strictly necessary.

The desire to communicate location information was evident in this condition. Before arranging the rendezvous location, all pairs either explicitly asked their partner where they were located or offered their location without being prompted. The exchange of location information often required further dialog to clarify the precise location (similar to excerpt from Andrew and Tina's narrative in Table 2). This ambiguity was common and demonstrates the difficultly participants had articulating their physical location. Once the location was agreed upon, they had no difficulty completing the rendezvous.

Although an awareness of their partner's location appeared to be important to participants, only two groups actually used the paper map to visually reference their partner's location. This suggests that the remainder of the pairs either felt they had an adequate understanding of where their partner was located or they didn't actually care, merely asking the question as part of the phatic dialogue.

Table 2. Andrew and Tina's illustrative narrative for Scenario 1 using the mobile telephone

A:	"Where are you?"
T:	"I'm on Dresden and Clyde. Just behind the Shoppers on Spring Garden, which is the corner of … Dresden and Spring Garden."
A:	"What? So you are at the Shoppers?"
T:	"No, I'm about half a block away."

All groups chose a rendezvous location that was familiar to either partners or a well-established landmark. The reliance on landmarks is consistent with previous literature that has shown that people frequently use landmarks to navigate [16, 20]. Additionally, research has shown that people are better able to recall and relocate locations/landmarks if they are close to well known or important intersections [16].

Condition 2: Location-aware handheld computer. All of the pairs relied on the location information during the rendezvous negotiation process (similar to Renee and Todd's narrative in Table 3), and all felt that they picked mutually beneficial locations for the rendezvous. The usefulness of the location information in selecting a rendezvous location was explicitly noted by seven of the eight pairs: "It was useful to see where your partner was.", "It was nice to see she was here and I was there … I just picked a middle point." The remaining participant commented that he "just chose a location then looked to see where [his] partner's location was".

Table 3. Renee and Todd's illustrative narrative for Scenario 1 using the location-aware handheld computer

Renee and Todd both arrived at their task locations at similar times. Todd decided to initiate the rendezvous with Renee. He looked at the handheld computer screen and noticed that Renee was just two blocks away on Dresden Row. Todd selected the top-left corner of the intersection of Spring Garden Road and Dresden Row for the rendezvous location. This point was midway between Renee's and Todd's locations. In the meantime, Renee looked at the screen on her handheld computer in preparation for requesting a rendezvous. A message appeared on Renee's screen indicating that Todd had suggested a rendezvous location. This looked fine to her so she acknowledged, accepting Todd's request.

Only one pair selected a physical landmark on the map (a building midway on the main road) as the rendezvous location. The remaining pairs selected a street corner on the main street between the partners' locations (which was relatively equidistant to both). This suggests that the participants felt comfortable using the icon representing the rendezvous location on the map as a point of reference (or "virtual" landmark) to facilitate navigation.

Condition 3: Mobile telephone and location-aware handheld computer. Despite being given both devices, six of the eight pairs used only the location-aware handheld computer to negotiate the rendezvous. These pairs exhibited similar behaviours to those in the handheld computer only condition. One pair used only the mobile telephone to negotiate the rendezvous. The final pair used both devices – the mobile telephone to first negotiate the rendezvous followed by the handheld computer to confirm the location.

The pairs that chose to use the handheld computer commented that they felt it would be easier and more convenient. The pair that chose to use the mobile telephone commented that they wanted to ensure an exact location was chosen. The pair that chose to use both devices used the mobile telephone initially because they felt it would be easier to converse and wanted to check and see if their partner needed anything.

3.9.2 Scenario 2: Why won't they respond?

In the second scenario, participants were asked to rendezvous at a pre-determined location, the Fireside Restaurant, which was then changed to Deco Restaurant. One partner was asked to notify the other of the new location, but no response was received.

Condition 1: Mobile telephone. All of the participants tried to initiate communication with their partner multiple times (similar to Nathan's narrative in Table 4). Four of the pairs called 2-3 times while the remaining four pairs called continuously.

Although one partner was instructed to inform the other of the location change, only half of the participants actually left voice messages for their partner. However, all of the participants proceeded to the new rendezvous location rather than the original meeting place. It is understandable why the participants who left a message went to the new location; they had communicated their intent in a form they perceived would be accessible by their partner (voice mail). However, the participants who did not leave a voice mail message also chose to proceed to the new location, despite the fact they had not notified their partner of the change. Only one of these participants exhibited any hesitation as to where to proceed. It is speculated this may be attributed to the artificiality of the scenario.

Table 4. Nathan's illustrative narrative for Scenario 2 using the mobile telephone

Nathan picked up the mobile telephone to call Robin and let her know about the change in plans. The call was not answered and was forwarded to a voice mail box. Nathan left a message for Robin:
N: "Hey. Fireside cancelled. We're going to have to go to Deco which is on the south side of Spring Garden, just beside Rockport. I will be hanging around out there. I will try to get a hold of you again. Cheers."
Nathan walked to Deco but continued to try to get a hold of Robin on the mobile telephone (6 times). He didn't stop calling until he was close enough to Deco and could see Robin standing in front of the Restaurant.

All rendezvous excluding one were accomplished easily since both partners proceeded to Deco. One rendezvous was considered difficult because one of the participants became increasingly agitated that his partner would not answer the mobile telephone or return his messages. This was the same person who was unsure of whether to proceed to the old or new rendezvous location.

Condition 2: Location-aware handheld computers. All the pairs made use of the location information provided on the handheld computer to observe their partner's movement and infer whether or not the request had been received (similar to Glen's narrative in Table 5).

All the groups except one chose to proceed to Deco after viewing their partner heading in that direction, "I saw [my] partner's dot move towards the location, confirming that he was heading there." The remaining participant headed directly to the new location, before receiving any indication that their partner was going to the new location. It is speculated that this may be attributed to the artificiality of the scenario. All of the pairs met up at Deco successfully.

Table 5. Glen's illustrative narrative for Scenario 2 using the location-aware handheld computer

Glen used the handheld computer to move the rendezvous point and suggest to Jill that they meet at the new location (Deco). Glen received no response from Jill so he continued to suggest the new location (using the handheld computer) as he walked toward Deco. He assumed that Jill would see the new location on the map and head there, even if she hadn't acknowledged his suggestion. Shortly thereafter, Glen saw Jill's location indicator moving towards Deco on the map, indicating to him that she received his message.

The number of times the new rendezvous location was suggested varied between groups. Half the groups made one or two requests, while the remaining four groups made three or more attempts. Most of the groups stopped suggesting the new location after they observed their partner heading to the new rendezvous: "I looked where he was going and saw he was heading towards the new rendezvous [location], so then I went there."

Condition 3: Mobile telephone and location-aware handheld computer. When arranging the rendezvous location, seven of the eight pairs chose to use both devices while the remaining pair used only the mobile telephone. Six of the pairs initially used the location-aware handheld computer to suggest the new rendezvous location and then followed-up with the mobile telephone when no response was received (similar to Michael's narrative in Table 6). When no response was received from the telephone call, several (6) of the pairs switched back and forth between the handheld computer and mobile telephone attempting to reach their partner: "I tried the handheld, then the cell, then the handheld

Table 6. Michael's illustrative narrative for Scenario 2 using both the mobile telephone and location-aware handheld computer

Michael used the handheld computer to suggest the new rendezvous location to Bill. No response was received from Bill. Michael decided to call Bill on the telephone. Bill didn't answer and the call was forwarded to voice mail. Michael left a message for Bill: M: "Hi Bill. This is Michael. We are supposed to meet at 5518 Spring Garden Road, Deco. So let me know. Bye." Michael glanced at his handheld computer and noticed that Bill was now at Deco and walked there.

again, then the cell again. I then saw where her dot was and I went there."

All of the groups used the location awareness provided by the handheld computer to decide how to proceed, and easily met up with their partner. Similar to the handheld computer only condition, all pairs chose to proceed to the new rendezvous location after observing their partner's location or movement. Even the participant that relied strictly on the mobile telephone to communicate the new rendezvous location used the location awareness information on the handheld computer to monitor her partner's progress.

3.9.3 Scenario 3: Why are they late?

In the third and final scenario, one partner was intentionally delayed by being asked to count a bag of pennies before proceeding to the rendezvous location (London Hair Design), making it difficult for them to arrive on time.

Condition 1: Mobile telephone. Three participants chose to call and check in when their

Table 7. Laura's illustrative narrative for Scenario 3 using the mobile telephone

Laura arrived first at London Hair Design (the rendezvous). Four minutes later when Vanessa still hadn't arrived, Laura took out her mobile telephone and called Vanessa.
L: "Hello."
V: "Hello."
L: "Hi. Where are you?"
V: "I am trying to find Curry Village, Brenton St. I can't find it. Where are you now?"
L: "I am at South Park. London Hair Design. I'm waiting for you."
V: "So you made it. Ok. I'll be there in about five minutes."
L: "Ok. Goodbye."
Laura continued to wait until Vanessa arrived three minutes later.

partner was late for the rendezvous (similar to Laura's narrative in Table 7). They all inquired where their partner was and why they were delayed. Two other participants chose to call their partner to let them know they were running late and would be late for the rendezvous. For the remaining three pairs, no calls were made. In the post-session interviews, two participants indicated that if the wait-time had been longer, they would have called their partner. A participant from the third pair indicated he would have called if he knew his partner was waiting at the rendezvous location. Interestingly, in both cases where the participant called to inform their partner that they would be late, the caller was not the partner that we intentionally delayed. These participants were running late because of navigational errors they committed. The participants who were delayed for reasons outside of their control (i.e., we asked them to count pennies) did not choose to call their partners to let them know they would be late. The reason they chose not to call is open for interpretation. It could be attributed to the artificiality of the task, or a need to complete the task quickly in an attempt to arrive at the rendezvous as soon as possible.

None of the participants left the rendezvous location to find their partner. One participant continually looked down the street trying to see their partner approaching; however, she was looking down the wrong street and was unaware of her partner approaching in the other direction. Despite the delay in the rendezvous, all pairs met without difficulty.

Condition 2: Location-aware handheld computer. All participants who arrived first made use of the location information while waiting. Upon arrival at the rendezvous location, they immediately checked their handheld computer to determine the location of their partner. These participants continued to monitor the progress of their partner until they

made visual contact. In four instances, the person waiting at the rendezvous location chose to walk toward their partner's location (similar to Emma's narrative in Table 8). The remaining four pairs waited at the rendezvous location for their partner to arrive.

Besides general concern over their partner being late, the location awareness did contribute to some uncertainty and confusion when the partner's location-indicator wasn't moving (while they were counting pennies). One participant explained that she was frustrated that her partner's location-indicator was not moving and she wanted to tell her to move up. Others expressed interest in knowing what their partner was doing and what was keeping them from completing the rendezvous.

Condition 3: Mobile telephone and location-aware handheld computer. All participants who arrived first utilized the location awareness information and immediately checked their handheld computer to determine the location of their partner. Four pairs also chose to communicate with their partner using the mobile telephone. In three cases, the waiting

Table 8. Emma's illustrative narrative for Scenario 3 using the location-aware handheld computer

Emma arrived first at the rendezvous location, on time. She checked her handheld computer to see where Natasha was. "Uh oh. Where is she going?" Emma looked up and down the street and frequently looked down at the handheld computer. Emma started making noises ("Whoa whoa whooooa") as Natasha appeared to be going the wrong way. Emma suggested a new rendezvous location on the corner of South Park St. and Brenton Place. She indicated that she wanted a quick rendezvous. She began to walk toward the new rendezvous location and saw Natasha approaching. They met up and walked to the final rendezvous location together.

participant placed a call to their partner to inquire where they were and why they were delayed (similar to Jessie's narrative in Table 9). In the fourth case, the delayed participant used the mobile telephone to call his partner to say he was running late and would arrive shortly. The remaining pairs simply monitored their partner's movements with the handheld computer and did not use the mobile telephones. None of the participants who were waiting left the rendezvous location to attempt to meet up with their partner.

3.9.4 Participant Comments

Participant feedback was collected during post session interviews. The participants provided comments and suggestions concerning a feature set that they believed would aid rendezvousing and better facilitate communication and coordination between partners. Many of the groups remarked that a text messaging system using pre-defined messages

Table 9. Jessie's illustrative narrative for scenario 3 using both the mobile telephone and location-aware handheld computer

Jessie arrived first at the rendezvous location. She observed her partner getting closer on the handheld computer. The next time she looked at the handheld computer her partner's location-indicator was no longer moving. Jessie picked up the mobile telephone and called Sandy.
J: "Hi. Are you still coming?"
S: "Hello. Hi. At some point. I have to count pennies first."
J: "Ohhh, ok. Have fun."
S: "Ok, I will."
J: "Call me if anything changes."
S: "Alright. Bye."
Jessie waited and shortly afterward Sandy arrived.

would be beneficial. They felt that typing full messages would be time consuming, but that navigating a simple, appropriately grouped, pull down menu with pre-defined messages such as “behind schedule”, “forgot something”, “can’t make it” would allow for quick communication. Most agreed that a system for sending a message that was unique to the situation would sometimes be needed, but thought appropriate pre-defined messages would be useful in many situations. Some suggested that rather than navigating menus or entering text, a simple map annotation could be used. Annotating the map would allow users to write messages directly on the map (e.g., “behind schedule”), draw arrows providing direction or symbols suggesting places to avoid (e.g., construction, traffic) or places of interest (e.g., sale at a store, interesting street performer). An additional suggestion was to have the location indicator representing each user convey additional information. Rather than a non-descript dot (as used in our study), additional contextual information could be conveyed by using an indicator similar to an emoticon (e.g., an emoticon flexing its bicep could indicate at the gym, an emoticon with a text bubble coming from its mouth could indicate talking). In such a case, the observing partner would be able to ascertain both user location and contextual information without obscuring additional map and screen information.

3.10 DISCUSSION

All of the pairs were able to complete the rendezvous tasks without much difficulty, regardless of the technology provided to the participants. However, close observation of the behavioural and communication differences demonstrates that the technology available significantly altered how the participants managed their social coordination. This section discusses differences in five key areas: communication efficiency; utilization

of location awareness; different information leads to different behaviours; limitations of location awareness, and privacy concerns.

3.10.1 Communication Efficiency

Mobile telephones are a familiar technology with which most people are well accustomed. Because of this, there are standard communication protocols that people use when communicating over telephones. For example, it is well known in the literature that people engage in phatic communication when they want to establish a speaking relationship [33, 39]. As such, arranging a rendezvous using a mobile telephone naturally follows these social norms.

Although phatic communication aids in the initiation and flow of verbal communication, in general, it provides little benefit to the rendezvous process as no location information is exchanged. Non-phatic communication provided by location awareness or from simple, pre-defined text messages has the potential to be much faster and more streamlined compared to standard verbal exchanges. The results from our study suggest that in some instances, this communication efficiency is desired. When participants had the choice of either device, they often chose location awareness over a verbal exchange with their partner. In addition, several of the participants expressed a desire for short, pre-defined text messages or map annotations to augment the location awareness available on the handheld devices. Some of the participants suggested pre-defined text messages such as “stuck in traffic”, “running late”, and ‘behind schedule”. It is interesting to note that these suggested messages are devoid of phatic structure; they are brief messages conveying only context.

It was also more efficient to gather information from the location-aware handheld computer than from mobile telephones. Social norms influence how comfortable people are making inquiries as to their partner's status [9]. For example, in the mobile telephone condition, when one partner was late for the rendezvous, the other partner always waited before calling to inquire about their state. In contrast, in the conditions involving the location-aware handheld computer, upon arriving at the rendezvous location, if the person's partner was not at the location, they immediately used the device to view their partner's location. In addition, the participants frequently (or constantly) monitored their partner's location using the handheld computer. It would typically be considered rude to continue calling someone on a mobile telephone to maintain a similar state of awareness. It is interesting to note that there can be a large variance in the length of time people feel it is appropriate to wait before engaging in a call (or a follow-up call). This individuality was clearly observed in our study.

3.10.2 Utilization of Awareness Information

Having access to location awareness has obvious benefits. Users can make more informed decisions and have a stronger sense of connectivity. The participants in our study made extensive use of the location awareness as a background communication channel to monitor their partner's location (as well as their own) in an unobtrusive manner. When people had access to both the location-aware handheld computer and a mobile telephone, they tended to use the handheld computer first to gather all relevant information and then followed-up with the mobile telephone if needed.

3.10.3 Different Information Leads to Different Behaviours

The amount and type of information available to people can influence their behaviours. This was evident from our observations of the third scenario (for all three conditions). In the mobile telephone condition, when one partner was waiting for the other, none chose to leave the rendezvous location in an attempt to meet their partner. This is not surprising given that without location information they may not have known where their partner was. Even if they used the mobile telephone to determine their partner's location, it would still have been difficult to infer the direction they would proceed in and subsequently be able to intercept them.

In the location-aware handheld computer condition, half of the participants chose to leave the rendezvous location to attempt to meet their partner. Being aware of their partner's location allowed them to easily find (and intercept) their partner. However, in the final condition when the participants had access to both a mobile telephone and a location-aware handheld computer, none of the participants chose to leave, although several participants chose to call their partner to inquire about their status. This suggests that the reason the participants left the rendezvous location in the location-aware handheld computer condition may have been more a result of missing contextual information (gained using the mobile telephone) rather than the ease with which they could meet up with their partner.

3.10.4 Limitations of Location Information

The results from our study clearly demonstrate that mobile telephones and location-aware devices have different roles in rendezvous behaviour. Mobile telephones are an easy

medium to assist people in communicating information about actions and intentions (e.g., "what are you are doing?" or "where are you planning to go?"). In contrast, sensor-based devices are very good at gathering overt contextual information, such as location, in a very unobtrusive manner. However, they provide little assistance in interpreting the associated state of the person. In our study, when participants were given both devices, they appeared to recognize the strengths of each device and utilized each appropriately (i.e., monitoring their partner's location with the handheld computer and using the mobile telephone to clarify what the person was doing).

In the location-aware handheld computer condition, several participants were confused about their partner's actions or believed that they were lost. As a result, these participants chose to leave the rendezvous location to try and meet up with their partner. In contrast, in the mobile telephone and location-aware handheld computer condition, the participants used the mobile telephone to call their partner and gather this information. This potentially gave them a better understanding of how their partner was proceeding, allowing them to make a more informed decision as to how the rendezvous was progressing. In our study, when telephone communication was initiated, all of the delayed partners indicated that they would be at the rendezvous location shortly so none of the participants waiting at the rendezvous location seemed to feel compelled to leave.

Before running this study, we felt that location awareness would always be beneficial to people attempting to rendezvous. In our third scenario, we observed instances where location awareness was extremely beneficial and other instances where it was unfavorable. It was beneficial because participants could see their partner's location and

track their progress in an unobtrusive manner. This arguably provided the waiting partner with enough information to wait contently. However, when their partner appeared to be lost or not making progress, it was very disconcerting to the waiting partner because they did not have enough information to determine what the problem was. This uncertainty was strong enough in some cases to actually draw the waiting partner away from the rendezvous location. Drawing the participants away from the location was identified as unfavorable for this scenario because the rendezvous location was the desired target. Depending on the scenario leaving could be interpreted as unfavorable or not.

3.10.5 Privacy Concerns

During post session interviews, a few participants commented on their concern over the continuous location awareness that our application provided. One comment made by a participant was the Orwellian "big brother" effect of location tracking technology. The same participant additionally commented that there are two sides to the location tracking issue. A guardian of a child might see this technology as a blessing, whereas the child could view it as an invasion of their independence.

In our system, monitoring a partner's progress was possible without interruption to the partner, or any indication that they were being monitored. Privacy concerns of background monitoring must be addressed given that technology adoption can be significantly affected by perceptions of the public. However, location awareness does not need to be continuous. It is a tool that can be used periodically to reinforce social activities such as a rendezvous. Prior research has shown that if users perceive the service to be useful, they are less concerned over their location being tracked and disclosed [3].

Outside of the context of the social activity, the location awareness feature could be turned off. People wanting the benefit of location awareness can actively choose to forgo their privacy during the rendezvous with a distinct group of people and regain their privacy upon completion. Obviously, hardware and device protocols must ensure that only the distinct groups would have access to the information.

Chapter Four: Automating Focus: Maintaining Relative Location Awareness

4.1 INTRODUCTION

Although a number of different presentations of location awareness information have been explored in previous literature [22, 27], there has been very little research on what location information users need to facilitate social coordination. This chapter describes a field simulation conducted to explore what map and location information was important to users and the level of detail they chose to view this information during a rendezvous.

4.2 STUDY DESIGN

Twelve participants completed three rendezvous scenarios specifically tailored to a university environment. The scenarios (described in section 4.6) were constructed from rendezvous experiences common to university students but general enough to be applicable to many different situations. All participants were given a location-aware map application running on a mobile device to assist them with their rendezvous activities. To help manage the high degree of participant variability likely in these scenarios, a scripted assistant was used as the participant's partner in the scenarios. Scripting the assistant allowed for better experimental control by helping ensure consistency between participants for each scenario.

4.3 PARTICIPANTS AND SETTING

Twelve participants (7 male and 5 female) between the ages of 20 – 34 years old took part in this study. Recruitment notices were sent to Dalhousie University faculty, staff, and students. Participants provided informed consent (see Appendix B) and were

compensated $10 for participation. All were daily computer users, with varying experience with mobile devices and location-aware technologies (e.g., GPS). Seven of the participants rarely (less than once a month) used mobile devices for anything other than telephone calls and had never used location-aware technology.

The study took place during the summer of 2005, on the Studley campus of Dalhousie University. Participants were recruited from the university community so all were familiar with the campus. Familiarity with the area was important because Colbert has observed that 80% of rendezvous take place in a familiar area [11].

4.4 HARDWARE AND SOFTWARE

The location-aware mobile device used in this study was an HP iPAQ h4155 handheld computer running custom location-aware map software (see Figure 5). The software

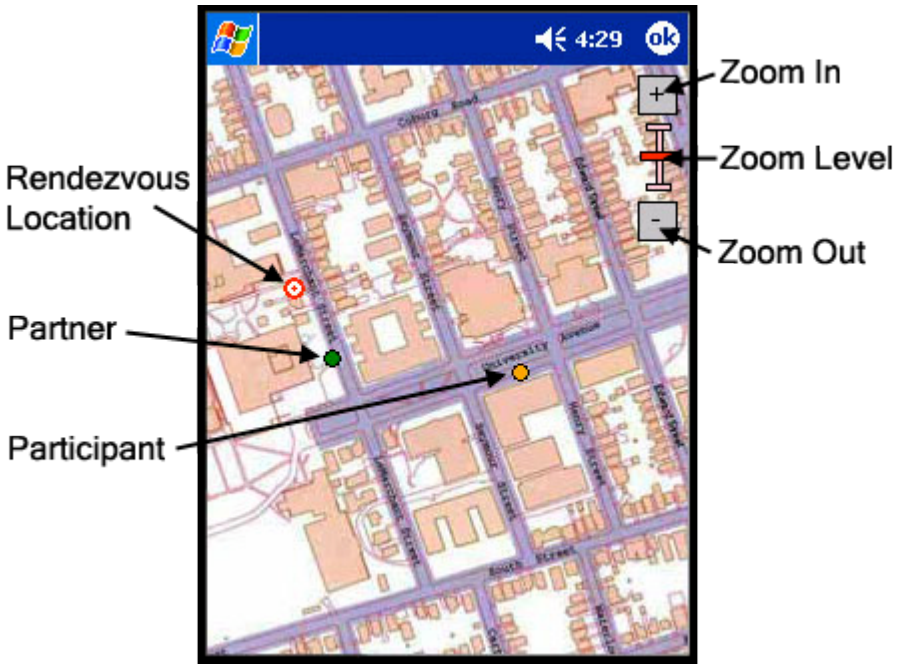


Figure 5. The location-aware map application interface.

displayed a colour map of the campus annotated with the participant's and their partner's location. The participant and partner location markers were represented by different coloured dots (participant = orange; partner = green). In two scenarios the map was also annotated with a target location marked by a red and white bull's-eye dot. Participants navigated the map with their finger or a stylus using a tap-and-drag technique.

The map was limited to the university campus and surrounding residential area. Three different zoom levels of the map were available (see Figure 6) each providing a different level of map detail: low, medium and high. Each level was accessible by using the "+" (zoom in) or "-" (zoom out) buttons available in the top right hand corner of the display. At all three levels, participants could scroll the map to view the complete region. This method of zoom was modeled after the technique used in Google Maps [36].

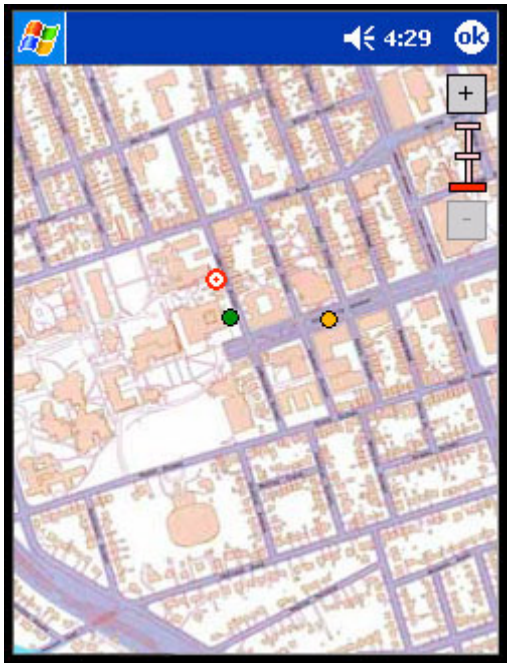
4.4.1 Low Level of Detail

At the lowest level of detail (i.e., zoomed out), the largest region of the map was visible, but with the least amount of detail (see Figure 6a). Street and buildings were distinguishable, but street names were not. Small cultural features[1] (e.g., walking paths) were not visible and it was impossible to discern the separation between small structures.

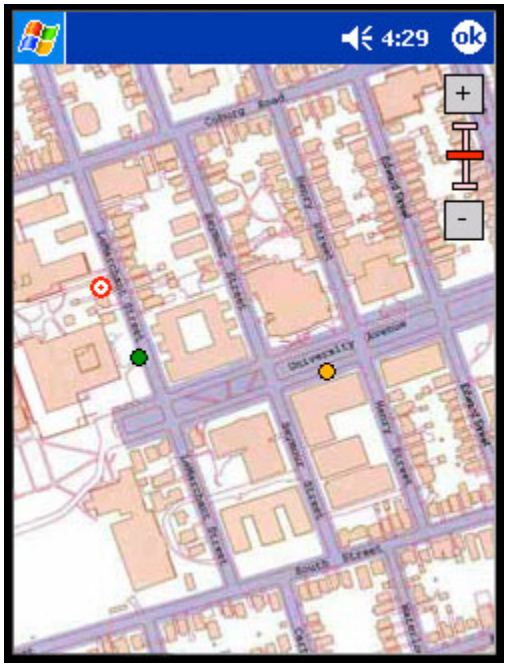
4.4.2 Medium Level of Detail

At the medium level of detail, a reduced region of the map was visible (when compared to the low detail level), but this region was displayed with more detail (see Figure 6b). It was possible (although not easy) to read street names and identify small cultural features.

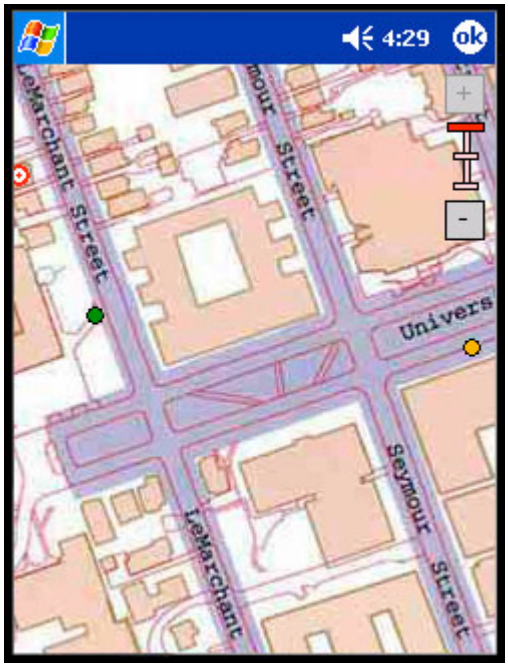
[1] A cultural feature is a person-made artifact.



a) Low level of detail.



b) Medium level of detail.



c) High level of detail.

Figure 6. The three different levels of map detail where (a) is the lowest and (c) is the highest.

4.4.3 High Level of Detail

At the highest level of detail (i.e., zoomed in), a focused region of the map was visible with the greatest detail (see Figure 6c). It was possible to easily read street names and identify small cultural features. The separation between small structures was visible, as well as distinguishing features on larger structures.

4.5 Using Wizard of Oz to Provide the Illusion of Location Awareness

As discussed previously for the first experiment (see Section 3.5) it was important that the location information provided by the devices be accurate and reliable, hence we again used our Wizard of Oz technique. The technique was modified for a single participant as per the experimental design (see Figure 7). A single wizard followed the participant

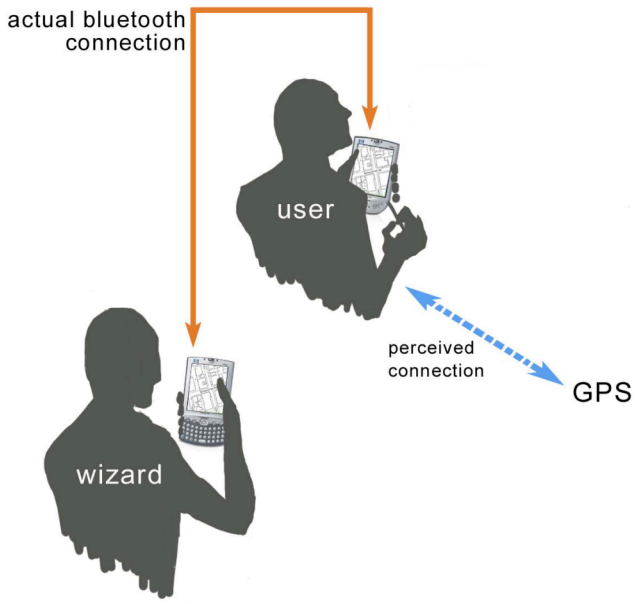


Figure 7. A Wizard of Oz technique was used to provide the illusion of location awareness to the participants.

around the experimental environment, sending location-information to the participant's device via a Bluetooth connection.

The location and movement of the scripted assistant was traced out and recorded prior to the study. The information was stored in logs and accessed by the software. The scripted assistant was given a handheld computer that they used to ensure they were in the correct position at all times during the tasks.

4.6 RENDEZVOUS SCENARIOS

The rendezvous scenarios used in this study were based on common rendezvous experiences of students in a university community: (1) performing a rendezvous at a previously agreed location when separated, (2) an un-planned rendezvous, and (3) a rendezvous at a previously agreed location when one partner mistakenly goes to a different location. The partner of the participant was the scripted assistant.

4.6.1 Scenario 1: Meet Me Here

The premise of the first scenario was that earlier in the day the participant and a friend, agreed to meet at a specific time and location on campus. Participants were instructed that they must rendezvous with their partner at the pre-determined location, the Science Co-operative Education Office at 1390 LeMarchant Street (see Figure 8).

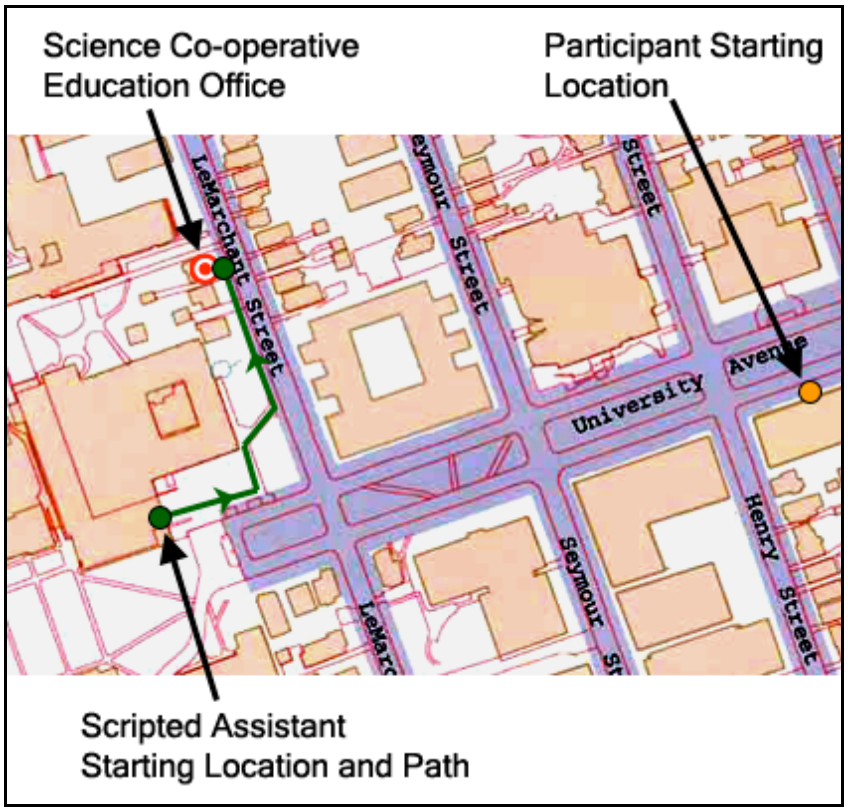


Figure 8. Scenario 1: Meet me here. The path of the scripted assistant is indicated by the directional line.

4.6.2 Scenario 2: Find Me Later

The premise of the second scenario was that earlier in the day the participant borrowed an item from his friend, but the friend needs it back today. He is very busy and indicated that he will not be able to arrange a meeting time, but that the participant should find him and return the item later in the day. Participants were instructed that they need to locate and meet up with their partner. The rendezvous would be spontaneous as no location had been pre-determined. The scripted partner was continuously moving so their location appeared dynamic to the participant (see Figure 9).

4.6.3 Scenario 3: Mistaken Location

The premise of the third scenario was that the participant and their friend have been working on a project together that needs to be submitted to the Humanities Ethics Department on campus which is located in the Arts and Administration Building. They have been working on separate sections of the project and need to assemble it before it can be submitted. Earlier in the day, the University Library was agreed upon as the place to meet and assemble the project before submitting it to the Ethics Department. However, the participant's friend (the scripted assistant) had forgotten about the Library meeting and proceeded directly to the Arts and Administration Building. Participants were instructed that they need to rendezvous with their partner at the initial location (Figure 10:

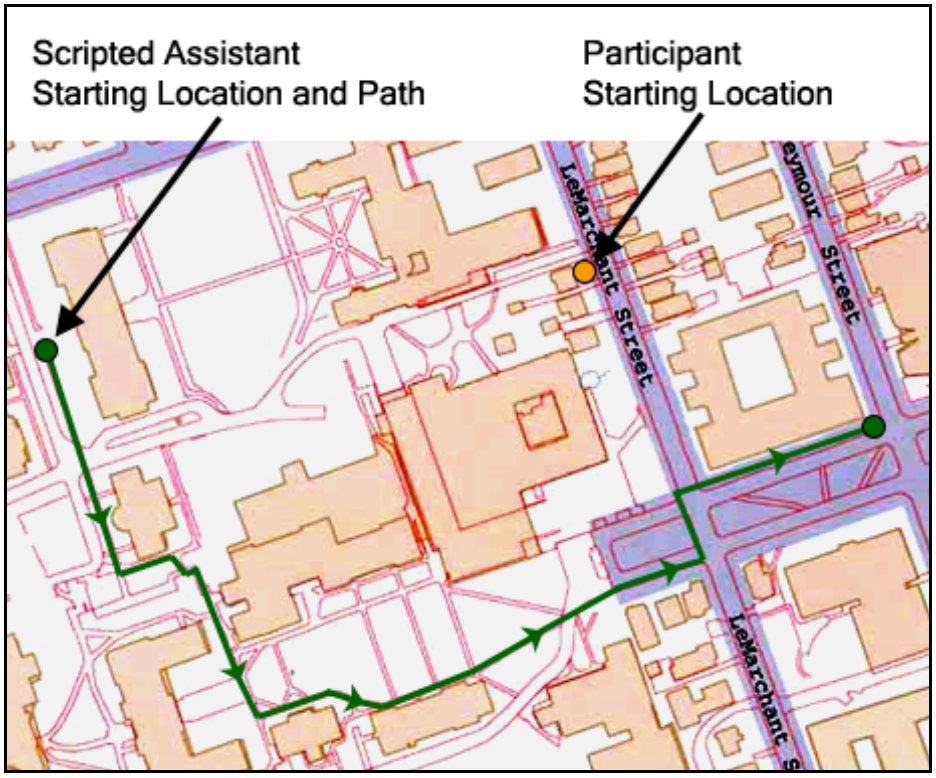


Figure 9. Scenario 2: Find me later. The path of the scripted assistant is indicated by the directional line.

the University Library) and then proceed to a second location together (the Arts and Administration Building). However, the scripted assistant did not arrive at the initial location and instead proceeded directly to the second location and waited there.

4.7 PROCEDURE

Each participant met the researchers at the entrance of the Computer Science building on campus and was asked to fill out a background questionnaire. Upon completion of the background questionnaire, each participant was briefed as to the nature of the study and the type of tasks they would be required to complete. The participants were informed that they would be performing three different rendezvous scenarios where they would have to

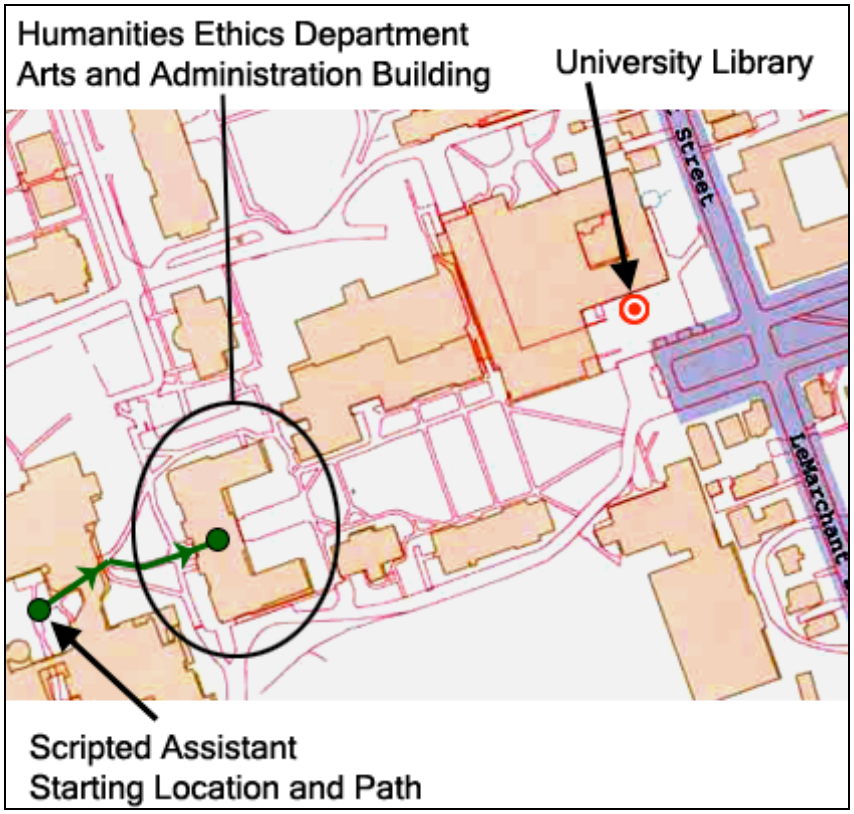


Figure 10. Scenario 3: Mistaken location. The path of the scripted assistant is indicated by the directional line.

meet up with a partner. The participants were told that after each scenario there would be a short interview concerning the scenario completed. Following this, the participants were introduced to their partner (a research assistant). The research assistant then proceeded to his starting location for the first scenario as directed. The participant was not informed that their partner was a research assistant working on the project. They were under the impression that this person was another participant in the study. The participant was then given an introduction to the mobile device and the location-aware map application. They were introduced to the features of the map (e.g., location indicators) and the application (e.g., panning and zooming) and were asked to explore the application until they were comfortable with its features.

To start each scenario, a scenario script was read to the participant and they were given a handheld computer and asked to proceed with the activity. The map on the handheld computer was initially set at the highest level of detail (i.e., zoomed out) with the participant's location marker centered on the screen. After each scenario, the participant gave the handheld computer back to the researcher and a post-scenario, semi-structured interview was conducted. When all three scenarios were complete, a post-session semi-structured interview was conducted.

4.8 DATA COLLECTION AND ANALYSIS

Data was collected via computer logging and semi-structured interviews (post-scenario and post-session). Data logging was used to reconstruct the actions of the participants and their usage of the mapping application. The logs were harvested for events allowing for a step by step visual reenactment of what was viewable on the participants' mobile device

screen. This data allowed us to identify map interactions (i.e., transition between detail levels and screen positioning) and information present on the screen (e.g., location of self, partner and/or a target location). The post-session interviews provided a qualitative perspective of the participant's general map usage and perceptions across scenarios. The transcripts from both interviews were analyzed and used to identify reasons for specific actions and to identify trends observed in the data logging.

4.9 RESULTS

Although each participant's experience was unique, numerous trends were observed within and between scenarios. In this section the trends observed for each scenario are reported, followed by a discussion of the overall trends across scenarios.

The results of each scenario are illustrated using a technique developed to present this study's results called a *participant flow diagram* (see Figure 11, Figure 12, and Figure 13). The participant flow diagrams flow downwards from top to bottom. Each interface actions and all currently visible locations are represented by a transition line. Each transition line begins with a number representing the number of participants performing the action. The width of the line reinforces this number.

4.9.1 Scenario 1: Meet Me Here

Participants' map interactions and visibility states for Scenario 1 are illustrated in the participant flow diagram shown in Figure 11.

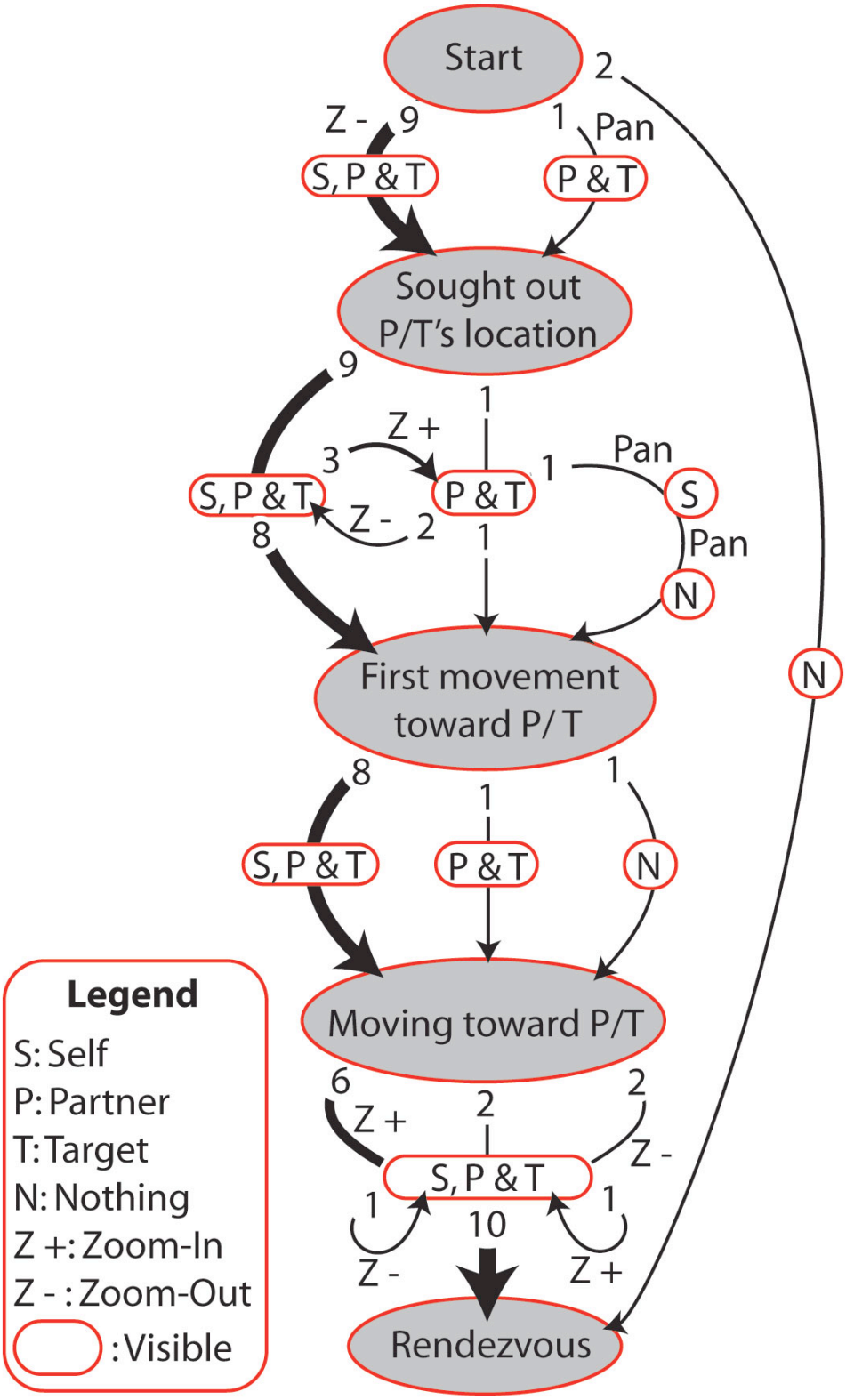


Figure 11. Participant flow diagram for Scenario 1.

Two participants chose not to use the map application, commenting that they were familiar with the rendezvous location and did not need to use the map software to find it. All ten participants who used the map application used it to initially find the location of their partner and/or target. Following this, the majority of participants (8) maintained an almost continual awareness of all three location markers (self, partner and target). Six of these participants always viewed the three markers, while the other two zoomed in briefly to view more detail on their partner/target location, but then immediately zoomed back out again. In addition, as the proximity between the participants and their target location decreased, six participants chose to zoom in to see additional map detail while the other two participants maintained a lower detail level for the whole scenario.

Of the remaining two participants, one chose an initial detailed view showing his partner and target markers, while the other chose to view the street ahead of him (i.e., no markers). Half way through the scenario, both zoomed out to view all three markers. As they approached the target location, both used the zoom feature to obtain a more detailed view (all three location markers were still visible).

4.9.2 Scenario 2: Find Me Later

Participants' map interactions and visibility states for Scenario 2 are illustrated in the participant flow diagram shown in Figure 12.

All twelve participants used the map application to initially find the location of their partner. Most participants (11) maintained an almost continual awareness of both location markers (self and partner). Eight of these participants always viewed the two markers.

The other three zoomed in briefly to see additional detail about their own locations, as well as their partner's location, but then immediately zoomed out again. In addition, as the proximity between the participants and their partner decreased, six participants used the zoom feature to see higher map detail while the other five maintained a lower detail level.

The remaining participant, after initially zooming out to find the location of his partner, then zoomed in to view greater map detail over his location. He briefly maintained this view and then panned the map so both markers were visible. He left the map in this position for the remainder of the scenario.

4.9.3 Scenario 3: Mistaken Location

Participants' map interactions and visibility states for Scenario 3 are illustrated in the participant flow diagram shown in Figure 13.

The third scenario was designed such that the participants would first proceed to the Library and then to the Administration Building. However, five participants chose not go to the Library, and proceeded directly to the Administration Building.

Half of the participants (6) initially used the map application to find the location of their partner. These participants maintained an almost continual awareness of all three markers (self, partner and target). Four of these participants always viewed the three markers, while the other two zoomed in briefly to view their own and their target location markers, and then either zoomed out again, or panned to view their partner's location. The other

six (5 of which went to the library first and did not manipulate the map[2]) had their marker and the Library target location initially visible. All of these participants zoomed out or panned to find the location of their partner, one when he started heading towards the Administration Building and the other four once they arrived at the Library. As they progressed towards their partner, five of the participants positioned the map to ensure that both their own and their partner's markers were visible. In addition, as the proximity between the participant and their partner decreased, half of the participants (6) used the zoom feature to see more map detail while maintaining their previously visible markers.

4.10 DISCUSSION

Participant map usage in this study strongly indicates the importance of the relationship between one's self, partner and/or target, in addition to the continual refinement of the visible map detail. It is evident from this study that, given a location-aware map application, there is no one specific way to use the application or reason to use a specific feature. This section discusses the results of this study in two areas: maintaining the visibility of self, partner and/or target, and map refinement.

4.10.1 Maintaining Visibility of Self, Partner and/or Target

Regardless of the scenario, the participants' usage of the application and comments in the interviews clearly demonstrated that maintaining the visibility of their location relative to their partner and/or target was important.

[2] The library is a prominent landmark and all participants would have known the location without the map software.

All participants who used the map application initially used it to determine the location of their partner and/or target. The majority of participants (27/34) accessed this information by initially zooming out thereby making all available location markers visible. Although zooming out revealed less detail, it allowed participants to easily ascertain the location of their partner and/or target relative to their current location. This information was particularly important at the start of the scenario because it allowed each participant to determine how they should proceed. One participant commented:

> "I just kept it zoomed out … I liked knowing where I was in relation to where he was."

When participants first moved towards their intended goal, most (29/34) chose to have all relevant location markers visible on the screen (i.e., self, partner, target) and many (22/34) continuously maintained this information throughout the scenario. However, there were instances when participants zoomed in to see greater map detail. Interviews with participants revealed three main reasons for zooming in: a) to see additional map details; b) to see their location relative to specific object on the map; and c) to help determine direction or orientation. Table 10 provides participants' comments illustrating the reasons they zoomed in.

A zoom in action was often followed by an immediate zoom out. This indicates that the need for detailed information was momentary, not continual, and less important than the need for the "bigger" picture. None of the participants used the application to solely focus on their, their partner's, or the target's location for an extended period of time. Another participant commented:

"… you get more information from it being zoomed out … because you can reference things better when you are zoomed out than when you are zoomed in."

4.10.2 Map Refinement

Given the importance of maintaining the relative position between the participant, their partner and/or target, it is obvious that participants would spent a great deal of time zoomed-out. However, as the proximity between the participants and their targets decreases, we would expect that having a more detailed view would be beneficial, particularly if all of the relevant location markers were still visible. The results for our study showed that 6-8 people (depending on the scenario) actively refined the map as they

Table 10. Comments illustrating the three main reasons (a, b, c) why participants chose to zoom in.

	Reason for Zooming In	Participant Comments
a	To see additional map details	"I just wanted to zoom in to see if I could see a shortcut to my partner."
b	To see their location relative to specific objects on the map	" … I zoomed in to get a street reference. To pinpoint where I was and then I zoomed back out to figure out [again] where he was …"
c	To help determine direction or orientation	"… to see which direction I am heading at that moment I can just move around … [at a high detail level] if I just stand there it doesn't indicate much about where I am heading … I need to move a long distance to see [where I am heading] … I will [zoom in] when I confuse my direction."

progressed through the scenario, zooming in to reveal more detail. Several participants commented on this during their interview:

> "… as soon as I figured out where he was I zoomed in enough so that both of us were visible on the map, but got enough detail so that I could figure out how to get there … and then at that point just kept zooming as I got closer to him."

Although there were 2-6 participants in each scenario that did not continue to refine the map, some participants may not have bothered because of the overhead involved. Our scenarios were quite simple and all of the participants were familiar with the map area. Many participants were able to complete the scenarios without requiring a lot of detailed location information.

Overall, the observed zooming actions and participant comments support the notion that at the beginning of a rendezvousing task, when there is a large separation, the relative position between the participant and their target was important. As the proximity between their partner and/or target location decreased, more refined choices (concerning direction) needed to be made, and more detailed map information became important.

Chapter Five: Design Implications

The results of each study have direct implications for the design of location-aware mapping applications used to facilitate rendezvous activities. The results of these studies are reflected upon to provide insights into design implications for location-aware devices to support social coordination.

5.1 STUDY 1

In Chapter 3 the usage of two devices, a mobile telephone and a location-aware handheld computer during a rendezvous were examined. Mobile telephones are an active communication channel that support rich verbal communication but are also obtrusive. Location-aware handheld applications provide a passive communication channel that facilitates background monitoring of users' locations. As demonstrated, both have specific advantages and disadvantages that our users generally understood and utilized. However, by recognizing these differences, we can improve on their strengths, minimize their weaknesses, and recognize the value of their boundaries.

5.1.1 Encode Additional Information into the Location Representation

Although location awareness was beneficial in both studies, it was also limiting because it provided users with only two pieces of information: where the participants were and in which direction they were moving. Participant comments and our observations suggest that it would be beneficial to encode additional complementary contextual information into the representation of the participant's location, such as temporal movement, or an

indication of their state (e.g., “I’m hurrying”, “I’m lost”). The additional information could provide observers with the context necessary to make better or more appropriate actions during the rendezvous process. However, the presentation must be managed appropriately ensuring that the representation is intuitive and easily understandable, and thus beneficial for social coordination.

5.1.2 Provide Multiple Levels of Detail for Communication

The results of Study 1 demonstrate that in some instances (e.g., Scenario 3: Why are they late?) participants wanted additional contextual information in addition to location. While an augmented representation, as discussed above may provide basic context, users will sometimes need richer channels of communication. Understanding users’ actions is easier with verbal communication over mobile telephones; however, social protocols often limit when people feel comfortable using this medium. This is partially due to the large overhead involved in initiating and participating in a telephone conversation. Location-aware applications should provide users with additional communicative functionality to enable them to provide and receive contextual information. For example, text messaging with either pre-defined or free-form messages can be an efficient communication method and is sometimes more appropriate than verbal communication. Providing multiple communication channels would allow participants to select the most appropriate channel for the message and situation.

5.1.3 Ease of Monitoring

In our study, any time a participant was waiting, they took advantage of the location awareness information to observe their partner’s progress. Although there was likely a

novelty factor in our study, keeping users informed of the status of the rendezvous may be a priority. Therefore, it is important to design the location-aware device to facilitate monitoring. This includes the physical form-factor of the device, the representation of the information on the screen, and any interactions with the device. A user should be able to quickly glance at the device and gather the necessary information.

5.1.4 Managing Privacy

During post-session interviews participants expressed concern over how their location information would be disclosed and the duration of the disclosure. As previously mentioned, privacy concerns must be recognized and appropriate support must be given to enable users to manage their privacy. Within the context of rendezvousing, assumptions were made that a user who wanted the benefit of location awareness for a rendezvous with friends would accept the short-term privacy implications. It is important to recognize the relationship between users since privacy concerns change when relationships between users change [26].

General suggestions to manage the privacy concerns associated with location awareness include providing users with control over whether or not their location is broadcast and to whom the information is sent. Additionally, subtle feedback could also be provided to a user to indicate that their location is currently being monitored, such as with Marmasse *et al.*'s "thinking of you" system [38].

5.2 STUDY 2

In Chapter 4 the focus was on the specific aspect of map usage for a location-aware handheld computer during a rendezvous. Interaction with mobile devices is inherently difficult because of the nature of the device and its size. It is important that the amount of interaction required be kept to a minimum and that the interaction techniques are appropriate for people on the move.

5.2.1 Visible Awareness

It was observed that the majority of participants maintained an almost continuous visual awareness of their position relative to that of their partner. The participants during the rendezvous would maintain an appropriate level of map zoom that would allow them to see their location and that of a rendezvous location or their partner. An application that supports coordination should facilitate users' awareness of their location relative to their partner(s) or rendezvous location.

Maintaining an awareness of numerous locations can be achieved in a number of ways. The simplest method would be to have the map at a zoom level where all locations of focus are visible as used in this experiment. Other methods could include using a simple technique such as Halos [4] for visualizing off-screen locations or the more complex fisheye views [19]. Halos would provide an awareness of off-screen partners or locations relative to the user's location and enable users to maintain a high level of detail without distortion of the information space (as would be seen with fisheye views).

5.2.2 Automated Map Refinement

As the proximity between the user and their partner and/or rendezvous location decreased, participants were observed zooming in the map to gain consistently greater detail. Performing the map refinement manually is a dexterous task depending on the implementation and is further complicated by mobility. To make applications useful in a mobile environment we should alleviate the need for interaction when appropriate. We believe that user guided automation of the map refinement as the proximity between the user and their partner and/or rendezvous location decreases would reduce the amount of interaction required.

5.2.3 Detailed Map Views

During their interviews, participants commented that zooming in provided the benefit of greater region specific map detail. The need for this detail was two-fold. First, they wanted details concerning their or their partner's location in relation to physical artifacts or landmarks. For example, building outlines would indicate if someone was in a building or standing outside, or even which entrance they were closer to. Second, they needed greater detail of a specific region to make informed decisions about how they should navigate the physical space. It was observed that our participants would zoom in to see and distinguish between cultural features (e.g., pedestrian paths, roads and structures). It is important to recognize that environment details can influence how we choose to navigate and these details should be presented in a in a clear distinguishable manner. For example, including pedestrian paths allows users to make more informed route choices rather than limiting them to street routes, as seen with conventional street maps.

Based on participant comments and observed device usage it is reasonable to speculate that small cultural features and region specific details do not need to be present while the map is zoomed out. While zoomed out we have seen that the users' focus is on the relationship between them and their partner(s) and understanding the region as a whole. Region specific details and small cultural features would only serve to clutter the map, increasing the complexity of the information space making it harder to interpret. As the user zooms in and their focus switches to a more constrained map region, small cultural features and region specific details should be apparent, becoming clearer with subsequent zoom-ins.

It is common in virtual map applications (e.g., Google maps [36]) and GPS based navigation systems to not include cultural features even in the most detailed view unless using satellite photographs. However, with satellite photographs there are issues of clarity and accuracy. For example, at the time of writing this thesis, the satellite image of Dalhousie University used on Google Maps [36] was not accurate. A new faculty of management building was built at 6100 University Avenue (opened September 2005) but is not represented in the satellite image. Inaccuracies could possibly lead to confusion, especially if there is a discrepancy in the area of focus. The maps commonly used for mapping applications are not typically satellite, but street maps. These maps are appropriate for street navigation because they are clean, simple and provide appropriate information for the activity (e.g., street outlines, names, and possibly traffic direction indicators). However, street maps are not appropriate for social coordination because they lack fine cultural and environmental details. It is important for the usability of a location-

aware map application to include cultural features as the user focuses on a specific map region, but not to the detriment of clarity and readability.

Chapter Six: Conclusions and Future Work

6.1 CONCLUSION

Location and context-aware computing is a quickly growing field that will impact our future social interactions because of the pervasive nature of mobile computing. It is therefore important to investigate how the introduction of mobile location awareness will influence and change our current social interaction and behaviours. This thesis takes a first look at how location awareness will influence how people rendezvous.

The results presented in the initial exploratory study (Chapter 3) clearly demonstrate that the choice of technology can impact behaviour during a rendezvous. The impact on behaviour is directly related to the different but complementary information a mobile telephone and location-aware handheld computer can easily and effectively convey. A verbal conversation using a mobile telephone allows for the exchange of contextual information about state and intentions, whereas a location-aware handheld computer provides an awareness of location. The awareness of location was beneficial to participants because it was utilized as a simple unobtrusive communication channel to monitor their and their partner's location and progress. Mobile telephones, although a rich communication medium, enforce social protocols which aid in initiating and continuing verbal communication. Location-aware technologies can avoid these social protocols by providing simple communication methods while still conveying location and basic contextual information. However, location does not convey enough information about a person's actions or state. As seen, there were instances where location information raised other concerns when it did not enable users to obtain a full understanding of their

partner's context. Augmenting a location application with voice capabilities allows users to contact one another and exchange contextual information to address their concerns if and when they need to.

The second study (Chapter 4) explored what map and location information users choose to focus on and the level of detail they chose to view, during a rendezvous. The importance of maintaining the visibility of a user's location relative to their partner and/or target was observed. In this study the users achieved this by maintaining an almost constant visible awareness of their location and that of their partner and/or target at a low level of map detail (i.e. zoomed out). Additionally, it was observed that as the proximity between users, their partner, and/or target decreases, the level of map detail required increases. On a mobile device, the manual refinement of map detail and maintaining visible location indicators can be a laborious task. The refinement process can be automated given user-guidance to alleviate the burden of interacting with the mobile device.

The results of this thesis are significant because they aid in the development of location-aware devices used to facilitate social coordination and inform future studies involving social coordination using location-aware devices.

6.2 FUTURE WORK

There is a great deal of future work that needs to be conducted. Understanding users' privacy needs is important for the adoption of location-aware technologies for use in social coordination. The issue of privacy in location tracking needs to be further

addressed when there is a perceived usefulness of the application. Additionally, an examination of the effectiveness of communication methods such as text messaging, virtual map annotations, and voice, is needed to better understand the communication needs of users.

The potential for automation and the subtle nuances of the automation process that can benefit mobile users needs to be further explored. Specifically, automating the visible relationship between a user, their partner and/or target needs additional examination. For example, when coordinating with numerous people, all at varying levels of proximity, how can detailed map information be provided while maintaining an awareness of the relative positions between of all people involved?

This thesis research has focused on rendezvous activity between two people. However Colbert [10] has observed that it is often the case that groups (two or more people) rendezvous. This group dynamic has yet to be explored within the context of social coordination. This is an important research direction because coordinating with a group is likely different than coordinating with one person. The complexity in managing and visualizing location information will grow with each additional partner.

Appendix A: Study 1 Informed Consent Form

Informed Consent Form

Exploring Handheld Technology in the Social Act of Rendezvousing

Principal Investigator: Mr. David Dearman, Computer Science Graduate Student
Contact Persons: Mr. David Dearman, Faculty of Computer Science, dearman@cs.dal.ca

We invite you to take part in a research study at Dalhousie University. Taking part in this study is voluntary and you may withdraw from the study at any time. There will be no repercussion from choosing not to participate in this study. The study is described below. This description tells you what you will be asked to do and includes any risks or inconvenience you might experience.

Participating in the study may not benefit you directly aside from getting the chance to use some interesting technology and the opportunity to advance research knowledge and potentially benefit others. There is a possible risk of frustration and embarrassment resulting from difficulties completing the tasks. $10 in compensation will be given for participating in this study and you may terminate your participation in the study at any time without prejudice. You should discuss any questions you have about this study with either of the principal investigators or with the assistant administering the study.

The purpose of this study is to explore the use of handheld technology in the social act of rendezvousing. You will initially be given a technology orientation explaining the handhelds and their functionality. Following the orientation a demographics survey will be given to determine demographics and technological background information. You will then be asked to perform a set of rendezvousing scenarios and tasks within the experimental environment using mobile devices. There are three different scenarios in total. An example rendezvousing scenario would be meeting with another person at a given location. After each rendezvous scenario you will be asked to complete a simple 2 item questionnaire concerning your perception of the rendezvous. After you have completed the set of rendezvous scenarios you and your partner will complete a semi-structured interview with the investigators exploring your rendezvous experience. The expected time to complete the session is 1 hour.

As you complete the rendezvous scenarios you will be followed and observed by the investigators. Observations during the session will be recorded using field notes, audio recording and computer logging. All personal and identifying data will be kept confidential. All results will be identified by a code, randomly assigned to the results for each subject, which cannot be used to identify you. This informed consent form will be kept in a secure location under confidentiality for five years post publication.

In the event that you have any difficulties with, or wish to voice concern about, any aspect of your participation in this study, you may contact Human Research Ethics / Integrity Coordinator at Dalhousie University's Office of Human Research Ethics and Integrity for assistance: ph.(902) 494-1462, email: patricia.lindley@dal.ca.

"I have read the explanation about this study. I have been given the opportunity to discuss it and my questions have been answered to my satisfaction. I hereby consent to take part in the study. However, I realize that my participation is voluntary and that I am free to withdraw from the study at any time.'"

Participant:	**Researcher:**
Name: _____	Name: _____
Signature: _____	Signature: _____
Date: _____	Date: _____

Appendix B: Study 2 Informed Consent Form

Informed Consent Form

Location awareness: Exploring Granularity and Presentation

Principal Investigator: Mr. David Dearman, Computer Science Graduate Student
Contact Persons: Mr. David Dearman, Faculty of Computer Science, dearman@cs.dal.ca

We invite you to take part in a research study at Dalhousie University. You are eligible to participate in this study if you are faculty, staff, or a student at Dalhousie.

You will be asked to participate in a study using handheld computers for a period of six days. The purpose of the study is to explore left-handed user interaction with left-aligned scrolling techniques on handheld computers. You will be asked to use the handheld software to record all foods you have consumed each day during the study period. The six days will be broken into two phases, where during each phase you will be using the same software however the scroll bar will change alignment between phases. You may terminate your participation in the study at any time without prejudice. You should discuss any questions you have with the principal investigator. Participating in the study will not benefit you directly, but we will gain valuable insight into handheld navigation techniques. There is a low risk that you may experience some fatigue or frustration in completing the activities.

At the beginning of the first session, you will be asked to fill out a background questionnaire detailing your previous experience using computers and handheld computers. You will then be given an introduction to the software used during the study. During phase 1 you will be using the software with a right-aligned scroll bar and during phase 2 you will be using the software with a left-aligned scroll bar. You will initially be assigned a phase, either 1 or 2 for the first three days, upon which you will switch to the other phase for the remaining 3 days. After the initial 3 days you will be required to come in for a post-phase questionnaire. Additionally, after the 6th day you will be required to come in for a second post-phase questionnaire and a semi-structured interview.

Interactions with the handheld during the experiment will be recorded using computer logging and audio recordings will be made of semi-structured interviews. All personal and identifying data will be kept confidential. Anonymity will be preserved by using pseudonyms in any presentation of textual data in journals or at conferences. The informed consent form and all research data will be kept in a secure location under confidentiality in accordance to University policy for 5 years post publication.

In the event that you have any difficulties with, or wish to voice concern about, any aspect of your participation in this study, you may contact Human Research Ethics / Integrity Coordinator at Dalhousie University's Office of Human Research Ethics and Integrity for assistance: phone: (902) 494-1462, email: patricia.lindley@dal.ca.

"I have read the explanation about this study. I have been given the opportunity to discuss it and my questions have been answered to my satisfaction. I hereby consent to take part in the study. However, I realize that my participation is voluntary and that I am free to withdraw from the study at any time.'"

Participant:	**Researcher:**
Name: _____	Name: _____
Signature: _____	Signature: _____
Date: _____	Date: _____

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