Opportunities Exist: Continuous Discovery of Places to Perform Activities

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ABSTRACT

A rich cognitive map of a space can enhance the individual's experience within the space. However, cognitive maps develop gradually through repeated experience; and because of this, on-demand mobile search services (*e.g.,* Google Maps, Yelp) are often used to compensate for missing knowledge. In this work, we developed and evaluated a context-aware place discovery application called Opportunities Exist to assist in the acquisition of spatial knowledge and meaning. The application differs from traditional search in that places are discovered using an activity (*e.g.,* drink coffee, sit in the sun) and the discovery process runs continuously, maintaining a history of places the user can perform her activities as she goes about her day. We conducted a 4-week deployment in two North American cities. The results show that users were able to discover new places to perform their activities in familiar spaces and learned to associate new activities with familiar places. In addition, participants leveraged the application to perform activities opportunistically, and used continuous place discovery as an opportunistic reminder of routines they wanted to break out of or resume.

Author Keywords

Activity, activities, Opportunities Exist, mobile, location-aware, continuous discovery, search

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Human Factors, Experimentation, Design

INTRODUCTION

An individual's cognitive map influences her ability to perform her daily activities [11]. The route she walks to work and the espresso bar she visits en route are activities influenced by spatial knowledge, and her ability to recall and sense meaning from the spaces. Spatial knowledge and meaning are not innate; they are gradually acquired with repeated experiences with a space [5, 16, 21]. Furthermore, the depth of meaning that an individual can sense from a space is influenced by the legibility or visibility of the space's meaning [18]. For example, a non-descript building does not visually convey the activities (or meaning) associated with the space, but the smell of baking bread wafting from an open window does suggest meaning for the place. Through personal experience—influenced by context—an individual can learn the activities she may perform in space, thereby assigning meaning to the space [1, 10, 14]. A community center is a place rich with many meanings; it can be a daycare in the day, a bingo hall at night and an electoral polling station every four years. The nature of an individual's experience with the community center is what defines its meaning [19], but dependent on the context in which it is experienced and the depth of its meaning may not be immediately obvious.

The acquisition of spatial knowledge and meaning (especially in new spaces) can enrich an individual's experiences in a space or place [9, 18]. However, a cognitive map develops gradually with repeated experience, meaning an individual will often have fragmented knowledge for the spaces she travels. Mobile information services (*e.g.,* Google Mobile, Yelp) are often used (on-demand) with varying degrees of success to compensate for this missing knowledge. Studies of mobile information needs [3, 7, 15, 22] show that individuals want greater access to location-information that is relevant to their activities and the spaces they frequently visit. Questions such as "*Where can I get mozzarella cheese closest to my route home?"* and *"What is something interesting to do around here?"* demonstrate the need for context-aware technologies that help with the acquisition of spatial knowledge and meaning in familiar spaces.

To assist in the acquisition of spatial knowledge and meaning, we developed Opportunities Exist, a context-aware place discovery application. Opportunities Exist differs from traditional on-demand search (*e.g.,* Google Maps) in that:

- Place discovery is achieved using specific activities (*i.e.,* ride bike) instead of generic keywords (*i.e.,* bike) that may associate alternate intentions to the object

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(*e.g.,* buy, repair, and tune). This method allows the user to find obvious and non-obvious places by conceptualizing what normally requires two steps (determine the types of places where an activity can be performed and then search to identify the existence/location of these places) as a simple expression of activity.

- The places discovered for an activity are relative to the user's current and future locations. The application maintains a list of activities and continues the discovery process as the user goes about her day—retaining a history of places that she can reflect upon.

We conducted a 4-week deployment of Opportunities Exist in two large North American cities. The results of the deployment show that:

- Continuous discovery of places to perform an activity helped participants acquire spatial knowledge and meaning for familiar spaces. Participants discovered new places in familiar spaces to perform their activities and learned to associate new activities with familiar places—activities they did not previous know could be performed at these places—exposing hidden meaning.
- Participants' use of the application led to changes in their spatial behaviour, enabling them to perform activities opportunistically. Continuous discovery of places to perform an activity provided opportunistic reminders and greater awareness of routines they wished to break or resume, and assisted in the decision making process.

Informed by the results, we discuss opportunities to support activities by highlighting places that have similar meaning, enabling the coordination and execution of activities within a family or social group, and allowing for opportunistic discovery of meaning without explicitly defining it.

RELATED WORK

A cognitive map is defined by Downs and Steas [11] as the process *"an individual acquires, codes, stores, recalls, and decodes information about the relative locations and attributes of phenomena in his everyday spatial environment."* The acquisition, organization and application of spatial knowledge and meaning (one's cognitive map) has a strong impact on an individual's ability to perform her daily activities—where an activity, in this paper, is an action that can be accomplished in a place (*e.g.,* drink a coffee, sit in the sun). A cognitive map is not innate; spatial knowledge and meaning is gradually acquired through repeated experiences [5, 6, 16, 21]. For example, an individual who recently moved to Manhattan will have greater difficulty navigating the city than a New Yorker who has lived in the city for 20 years. However, 20 years of residency does not mean the New Yorker knows everything there is to know about Manhattan.

An individual discovers the meaning of a space by experiencing the space. However, a space is never experienced in isolation; the experience is relative to the individual's surroundings, the events that lead to the experience, and previous experiences in the space [18]. In addition, the ability to discover meaning is influenced by its legibility and visibility [18]. For example, buying a hotdog from a street vendor when walking through a local park, or stopping to smell baking bread wafting from an open window are experiences (or activities) that an individual can use to assign meaning to a space. But, on a rainy day the hotdog vendor may not setup in the park or the building may close its windows to keep the wind out. An individual experiencing the park or walking by the building on the rainy day will undoubtedly associate different meaning with these spaces. The context in which an individual experiences a space will define the meaning she assigns to the place [1, 10, 14]. With respect to activities, they can be temporal, as in the example of the community center. Even though people following spatially and temporally reproducible patterns [12], repeated experiences with a space does not imply that an individual will know all the activities she can perform in the space, meaning is often hidden and may not be immediately obvious.

The greater an individual's spatial knowledge and meaning for a space, the richer her experiences will be in the space [9, 18]. If an individual knows that two espresso bars (kitty corner to one another) both make a good latte, but only one sells cupcakes, then the individual (assuming she likes cupcakes) can have a richer experience in the space. Unfortunately, an individual's cognitive map will always have gaps regardless of how often she frequents a space [11, 21]. Mobile information services (*e.g.,* Google Mobile, Yelp) compensate for missing location-based knowledge by allowing an individual to supplement her knowledge on-demand, but these services vary in terms of success. Location-based reminder systems [2, 13, 23] allow an individual to associate meaning or action with a location (*e.g.,* remember to buy postage stamps), but the reminder is only accessible in the location defined by the user. However, studies of mobile information need [7, 15, 22] and mobile search [3, 4] show that individuals want greater access to context-aware services on-the-go to support their activities and indirectly their cognitive map. In this work, we leverage activities (as opposed to traditional keyword search) as the search grammar to facilitate the discovery of places. Work by Dearman and Truong [8], and Shanahan *et al.* [20] have explored methods to identify the activities (*i.e.,* meaning) that can be performed in a place. In particular, we build upon the work of Dearman and Truong who use community authored content as a knowledge source for activities that can be performed in a place, for places on a city scale [8]. We believe that the use of community authored content can help discover non-obvious places where an activity can be performed, because the activity-place association is derived from the expression of personal experience.

OPPORTUNITIES EXIST APPLICATION

Opportunities Exist is a mobile application that is designed to assist the mobile user by gradually discovering places

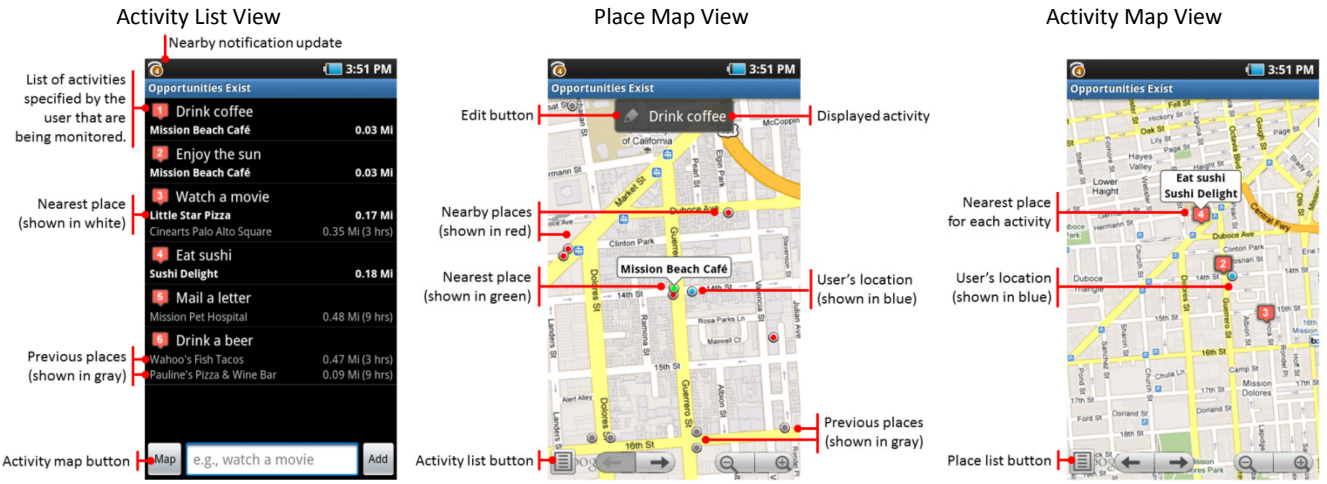

Figure 1. The interfaces for Opportunities Exist; excluding the place list view. The activity list shows all the activities entered into the application sorted by the nearest potential place; this is the default view. The place map shows the location of potential places to perform a specific activity. The activity map shows the location of the nearest potential place for all the activities.

where she can perform her activities, near her current location and all future locations she will visit. Unlike a traditional location-based search service (*e.g.,* Google Mobile, Yelp) that allows the user to conduct on demand searches with keywords, Opportunities Exist performs on demand and continuous discovery of places where the user can perform her activities. For example, if a user wants to acquire knowledge about *"places to ride a bike?"* or where there is *"something interesting to do around here?"* she can use the intended activities (*i.e., ride bike*, *do something interesting*) not generic key phrases (*e.g., bike*, *community center*, or *interesting places*).

High-Level Design

Opportunities Exist facilitates the acquisition of spatial knowledge and meaning over time in spaces where a mobile user travels. The application—which runs continuously on the user's mobile device—maintains a list of activities that are of interest to the user (Figure 1). The type of activities can include to-do items that the user wants to perform, casual activities the user may be interested in, or activities the user already performs but wants to learn more places to perform the activity. The intent is to help the user discover opportunistic places to perform her activities, with respect to her current location. The *activity list* view (Figure 1) presents the activity and place information in a glanceable list format. The short history of places helps the user identify the availability of places to perform the activity in previously traveled spaces.

As the user goes about her day, the application continuously searches for places (centered on her current location) where she can perform her list of activities. The application maintains a record of all the discovered places so the user can review the places (in the spaces she had been) at a later time. The search process is continuous, updating at set intervals, and requires no additional input from the user.

Implementation Details

An activity is articulated by a user as a grammatically natural verb-noun pair. For example, if the user is looking to discover places where she can drink a coffee, she could enter *drink a coffee*, *buy a coffee*, or *purchase a latte*. Similarly, if the user is interested in places where she can relax in the sun, she could enter *relax in the sun*, or *enjoy the sun*.

Opportunities Exist consists of a Web-service implemented as a Tomcat servlet (*OpportunityService*) and a native client (*OpportunityClient*) implemented as an Android mobile phone application. The *OpportunityClient* runs continuously while the mobile phone is on and starts automatically on boot-up. The user enters an activity string (*e.g.,* relax in the sun) into the *OpportunityClient* which is sent to the *OpportunityService* to be parsed[1] to identify the verb (*i.e.,* relax) and noun (*i.e.,* sun). The verb-noun pair is returned to the *OpportunityClient* and stored locally on the user's device.

The *OpportunityClient* uses the activity (as a verb-noun pair) and the user's current location to identify potential places to perform the activity by querying a location-based activity service (*ActivityService*) implemented by Dearman and Truong [8]. Dearman and Truong's evaluation of the *ActivityService* revealed a mean precision up to 79.3% and recall up to 55.9%; as a result, false positives do occur, and we do not attempt to identify and remove them. The query to the *ActivityService* is constrained to within 1 Km of the user's location, and limited to the 10 nearest places. The *OpportunityClient* continuously queries the *ActivityService* at an interval defined by the user—set to 5 minutes increments between 10 and 60 minutes. The *OpportunityClient* stores all the places returned by the *ActivityService* for 96 hours.

The interface for Opportunities Exist is comprised of four primary views (Figure 1): the *activity list* (the default view),

[1] http://nlp.standord.edu/software/tagger.html

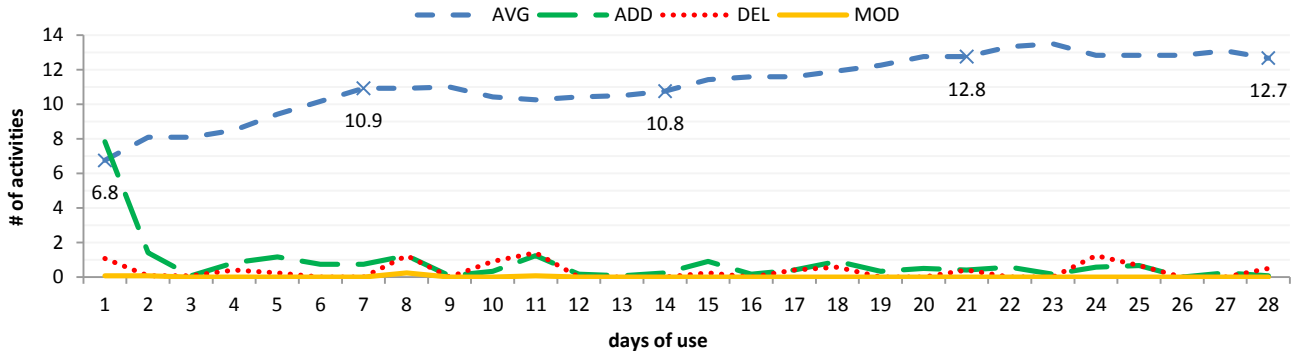

Figure 2. The average (AVG) number of activities a participant entered into their list over the course of the 28 days. In addition, the average number of activities added (ADD), deleted (DEL) and modified (MOD) on a given day.

the *activity map*, the *location map*, and the *location list*. The a*ctivity list view* presents the user with a scrollable list of the activities she has entered into the application. The activities are ordered (top-down) by their relative distance from the user's current location to the closest potential place to perform the respective activity. In addition to the nearest potential place, a short list of up to two historic nearest potential places is also shown. The a*ctivity map view* is a simplified map visualization of the *activity list view*—only the nearest potential place for an activity is shown on the map. Touching the activity/place marker enables a balloon popup that shows the activity and place name. Touching the balloon popup brings up a window that shows additional contextual information: address, telephone number, a link to the place's Yelp reviews, and an option to mark the activity is *wrong* for the place. The *location map view* displays all the places maintained by the application for an activity. This view is accessed by pressing an activity in the *activity list view*. The nearest (green), nearby (red) and history places (grey) are indicated with different colour markers (Figure 1). Touching a marker brings up a window containing additional contextual information for the place. In this view, we implemented functionality so the user can add a new place for the activity, which is then reflected in the *ActivityService*. The *location list view* is a textual listing of all the places for the respective activity. The places are ordered (top-down) by relative distance from the user's current location.

USER STUDY

We conducted a 4-week deployment of Opportunities Exist in two North American cities; San Francisco, California and Toronto, Ontario. We chose these cities because dense metropolitan areas are well supported by the *ActivityService*. The purpose of the deployment was to identify how the application could assist daily activities and evaluate if continuous place discovery could assist in the acquisition of special knowledge and meaning. We did not collect a baseline metric (*e.g.,* Google Maps mobile) with which to compare the application because 1) prior research has shown that implicit location-based search constitutes a small percentage (~15%) of mobile searches [4] and 2) the application's intent is to complement traditional on-demand search by satisfying a different need.

Participants

Twelve participants were recruited though a posting on Craigslist—1 female and 11 male. Three participants were recruited in Toronto and nine in San Francisco. Participation was open to anyone 18 years or older who lived in either city and owned an Android mobile phone with an active data plan. We attempted to maintain a balance in recruitment between the two cities; however, it was significantly more difficult to find Android users in Toronto.

The majority of participants were between 20 and 29 years of age: 18-19 (1), 20-29 (6), 30-39 (3), 40-49 (2). The types of Android mobile phones owned by the participants varied (*e.g.,* Nexus One, Motorola Droid, HTC Hero, G1). All participants were experienced and frequent users of mobile search services such as Google Mobile and Yelp.

Procedure

Each participant installed Opportunities Exist from the Android Market Place and used the application for 4 consecutive weeks. The application was installed during an initial interview that was conducted in-person with a member of the research team. During the initial interview, we introduced the application as a *tool that discovers where activities can be potentially performed* and provided a detailed walkthrough of its interface. We emphasized that the process of discovering places is achieved using activities structured as verb-noun pairs. At the end of the interview, we encouraged participants to add up to five activities to ensure they understood how to structure an activity as a verb-noun pair. Participants chose activities they frequently performed or wanted to know more about; we did not provide activities.

Every seven days, we conducted a 30-minute phone interview with each participant. The phone interview followed a semi-structured format exploring the participant's use of the application. The interviewer probed how the participant used the application and specific instances when it was useful and not useful.

Every three to four days (twice a week) we sent the participants a system generated online survey that listed all their activities with a matched place. We listed each activity at least twice; matched with one randomly chosen *closest*

place and one randomly chosen *nearby place*. In the case that no places existed for an activity, the activity was not shown in the survey. In addition, the survey generator randomly selected a small number of activities and matched it with a random place that the application did not discover for that activity. For each match, we asked three questions: *Did the application discover this place for this activity?* (Yes, No, Maybe); *How confident are you this activity can be performed at this place?* (5 point Likert scale: 1—Not confident; 5—Confident); and, *Indicate your prior awareness for this place and activity* (chosen from a list of five possible responses and one *other* response).

At the end of the fourth week, we conducted an in–person exit interview. The exit interview followed a semi-structured format, probing the participant's reason to add each activity and the usefulness of the application for each activity. We compensated each participant $100 (CDN or USD depending on their locale) after the exit interview.

RESULTS AND OBSERVATIONS

All participants (12) completed the 4-week deployment. Participants entered 273 activities, 265 of which were correctly articulated as a verb-noun pair; the other eight entries were articulated as a keyword (*e.g.,* coffee, thrift store) and not as an activity, so no results were provided by the *ActivityService*. For the purpose of the analysis we will only discuss the 265 valid activities. The average number of activities entered by a participant was 22.1 (*SD*=10.1, *min*=9, *max*=38). At any given time the average number of activities in a participant's list was 11.1 (*SD*=3.8, *min*=0, *max*=21). The average number of activities in a participant's list grew from 6.8 on day 1 to 12.7 on day 28 (Figure 2). The majority of activities (201/265) were classified by participants as long term/recurring activities, such that there was no immediate need to perform the activity. Sixteen activities were classified as immediate and 48 were both immediate and long term/recurring. The average number of daily interactions with the application was 4.8 (*SD*=2.7, *min*=1.8, *max*=12.9).

The 20+ hours of participant interviews were fully transcribed and rigorously analyzed using open-coding by two coders. The points of discussion below are derived from the open-coding analysis and exemplar quotes are used to reinforce our findings. We do not differentiate between the Toronto and San Francisco participants in the analysis because the disparity in the recruitment for the locales resulted in negligible differences.

How Participants Structured Their Activities

The types of activities participants entered into the application were as unique as the participants. Activities include but are not limited to: *buy groceries*, *drink coffee*, *eat steak*, *recycle cans*, *buy used clothing*, *withdraw money*, *make a bonfire*, and *play pinball*. The 265 activities represent 209 unique verb-noun pairs, 35 of which were entered by one or more participant. The activities were more variable in the choice of noun (176 different) than verb (38 different). Although we argued that articulating an activity as a verb-noun pair is grammatically natural, participants struggled with the grammar and granularity they should use to define their activities, and in some cases showed influence of traditional search behavior.

Multiple Activities Can Express a Single Intent

Traditional on-demand search services (*e.g.,* Google Mobile, Yelp) typically involve multiple iterations of a query as the user refines their need [17]. With Opportunities Exist, the discovery process is both on-demand and continuous; meaning the process of refining an activity can be considerably longer. If no places were discovered or the places were wrong, participants were unsure if the activity they entered was *"working right"*, or if they just needed to give it time. To cope with the uncertainty, participants used three methods to achieve greater coverage for their activity:

- *Vary the verb* – change the verb to use a synonym or similar word, but keep the same noun (*e.g.,* T3 entered both *get iced tea* and *drink iced tea*).
- *Refine the noun's specificity* – enter multiple activities changing the specificity/granularity of the noun (*e.g.,* S5 entered both *eat vegan* and *eat tofu*).
- *Broaden the activity* – redefine the activity to be more generic (*e.g.,* to find an ATM, S1 entered both *withdraw money* and *deposit money,* later changing *withdraw money* to *visit a bank*).

These coping methods resulted in participants having at least two activities in their list at the same time for the same intent: the 265 activities represented 174 unique needs.

Defining an Activity as an Action or Place

Participants articulated the majority of activities (217/265; 81.9%) in terms of the *action* (*e.g.,* drink a beer) they were interested in, but some activities (48/265; 18.1%) were articulated in terms of a *place* (*e.g.,* find a bar) where they could perform the action. We envisioned that participants would define their activities in terms of the *action*, not the *place*. An activity that was defined as the *action* were rated as significantly more useful (*median*=4, *M*=3.57, *SD*=1.43) than an activity defined as the *place* (*median*=3, *M*=2.71, *SD*=1.62), $F(1,263)=13.63$, $p<0.001$.

Conditional Operators and Activities

Although Opportunities Exist is not a traditional search service, participants still wanted to apply traditional search operators to the activities. We instructed participants in the initial interview that conditional operators would not work, however three participants still tried: *buy records or music*; *eat a meal for under $4*; and, *eat dinner not Asian*.

Recognition of Place and Associated Activities

Analysis of the twice-weekly survey data shows that participants were able to correctly recognize and associate their activities with places the application discovered. They correctly recognized 70.2% of the *closest places*, 58.5% of the *nearby places*, and incorrectly recognized 36.3% of the *wrong places* we injected (Table 1). This result suggests that participants can recognize an activity with respect to a place (by name) and that recognition is higher for the *closest places* which were displayed beneath their respective activity on the

Group	Yes N (%)	No N (%)	Maybe N (%)	Total
Closest	610 (70.2)	111 (12.8)	148 (17.0)	869
Nearby	431 (58.5)	115 (15.6)	191 (25.9)	737
Wrong	57 (36.3)	56 (35.7)	44 (28.0)	157

Table 1. The relative percentage of closest, nearby and wrong activity-location pairs that were presented to participants in the twice-weekly survey that they indicated they were shown by the application (Yes), not shown by the application (No), or were not sure (Maybe).

default *activity list view*, rather than the *nearby places* which required the participant to navigate to the *location map view* or *location list view*.

Participants rated their confidence on the ability to perform the activity at the matched place greater for the correct places (the combined *closest* and *nearby places*: *median*=4, *M*=3.71, *SD*=1.54) than the *wrong places* (*median*=2, *M*=2.32, *SD*=1.53), $F(1,1092) = 43.30, p<0.001$. The majority of places that participants recognized as discovered for an activity and they were confident (*somewhat confident* or *confident* combined) the activity could be performed at the place, were familiar and already known for the activity (Table 2: 349/650; 53.7%). However, many of the places were new (201/650; 30.9%) or the place was familiar but not already known for the activity (55/650; 8.5%). The twice-weekly survey responses show that participants were able to discover new places in the spaces they visited, and associate new activities with familiar places.

The Usefulness of Opportunities Exist

Participants found Opportunities Exist useful in a variety of ways. For each activity a participant entered, we asked the participant (in the exit interview) to rate the usefulness of the application for this activity (5-point Likert scale: 1-not useful; 5-useful). We did not define useful; the definition was left open to the participants' interpretation. The average usefulness of the application for an activity was 3.42 (*SD*=1.50) with a median usefulness of 4 (somewhat useful). All (12) of the participants found the application useful (Likert scale: 5) for three or more of their activities (Figure 3: *M*=7.42, *SD*=5.57, *max*=21) and somewhat useful (Likert scale: 4) for two or more of their activities (Figure 3: *M*=4.75, *SD*=2.93, *max*=12). In the weekly and

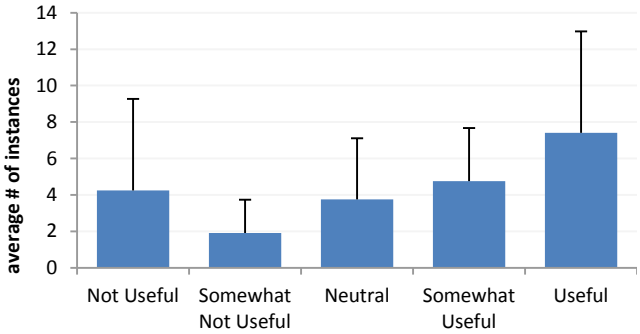

Figure 3. Average number of instance for each usefulness rating and the standard deviation.

Awareness Responses	N (%)
Already aware of the place and that the activity can be performed here	349 (53.7)
Not aware of the place and that the activity can be performed here	201 (30.9)
Already aware of the place, but not that the activity can be performed here	55 (08.6)
Forgot about the place, but was reminded	32 (4.9)
Forgot the activity can be performed here	10 (1.5)
Other – None of the above	3 (0.5)

Table 2. Responses from the twice-weekly survey for the participants' awareness of the location and activity. The data presented is only for places they successfully recognized and were confident the activity could be performed at the place.

exit interviews, participants disclosed a variety of ways they found the application useful. In the remainder of this section, we will discuss how the application was useful for spatial knowledge and spatial behaviour.

Knowledge: Discover New Places in Familiar Spaces

All (12) participants commented that the application was useful by helping them discover new places in familiar spaces; confirming the findings of the twice-weekly survey. The places the application discovered were always centered on the participants' location and therefore relative to the routes they travel. Participants S3 and S6 discussed that even near their home and work—both very familiar spaces—they discovered a new place to perform an activity and performed the activity at this place:

[S3—buy stamps] *"I did find some new places…one right next to me…Jenson's Mail. It is in an area where Safeway is which is where I do some of my shopping so it was like whoa, I didn't know I could go here…the other post office is like 4 miles away. I ran out so it was perfect timing."*

[S6—play soccer] *"It did help me find Columbus Park …I've probably been to that soccer field like 5 times [since discovering it]…it is small enough that a lot of people don't go there but big enough that you can get a game going. The area is really familiar, it is right next to work, but I guess it was a street I've never been up. It is really easy to pass by."*

The experience of participants S3 and S6 highlight the discontinuity in spatial knowledge even in familiar spaces. Being familiar with a space does not mean an individual possesses full knowledge of the places within the space. The application was able to assist their spatial knowledge by discovering new places along a path less travelled.

Knowledge: Associate a New Activity with a Familiar Place

A minority of participants (4) commented on one or more experiences when the application helped them associate a new activity with a familiar place. Participant S3 discussed that for *play basketball* the application showed him a familiar local sports complex that he previously thought *"was only for soccer"*, but discovered that "*there is basketball there too."* Similarly, participant T3 who was interested in learning

about new local music venues discussed that he is *"aware of the Gladstone Hotel, but not as a concert venue."* Even though S3 and T3 were familiar with both places, they had not previously associated the place with the respective activities. The application was able to assist them by revealing meanings that they were not aware of previously.

Knowledge: Discover New Places in Unfamiliar Spaces

Three participants commented on one or more experiences when the application helped them discover a new place in an unfamiliar space; a place they would not have discovered otherwise. Participant S9 who had just moved to the American city a week prior to starting the deployment epitomized this sentiment. S9 commented that the application *"pointed me to places I was not aware of, literally places that are across the street from me. Needing to do laundry and realizing there was a place across the street…it was very helpful."* Participant S6 who was house hunting in a new neighbourhood discussed an experience when the application discovered a place where he could take his three year old son to *have a bowl of soup*:

"Last weekend while we were out house hunting, Noah was complaining that he was hungry…so we just checked out the 'have a bowl of soup' [an activity already on his list] and sure enough there was a Boulangerie nearby. We just wandered over and Noah got his soup."

In these unfamiliar spaces, participant S9 and S6 possessed little spatial knowledge to inform their spatial decisions. The application was able to assist the participants by providing the spatial knowledge and meaning they could use to make a decision and perform their activity.

Knowledge: Random Place and Activity Discovery

The majority (8) of participants found the application not useful for one or more activities (Figure 3: M=4.25, SD=5.03, max=13) and somewhat not useful for one or more activity (Figure 3: M=1.92, SD=1.83, max=6). In both instances, no place was discovered or the places discovered were *"completely wrong."* However, four participants found a silver lining, identifying a place that was interesting albeit wrong for the activity:

"… with 'eat Mexican' it gave me a cheese steak shop. I researched it on Yelp and it had some good reviews and it was close to home. It is now on my radar."

Participant S3 did not find a place to *eat Mexican* using the application, but in sifting through the seemingly random places he was able to discover a new cheese steak shop. The application, although not useful for the intended activity, was able to assist the user find a place to perform an activity they had not thought to add to the application.

Behaviour: Break Out or Get back into a Routine

Two participants commented that the ability to discover places in their current space and the spaces they visit (without effort) helped them break out of a routine. Participant T3 was reminded that he can buy his fruits, vegetables and produce in Kensington Market—a small neighbourhood comprised of many small markets—rather than the large box store he currently frequents:

"It was actually useful for 'buy fresh fruit' and 'buy meat', two things that I always do…at Metro and I feel like I should try to branch out and find local little fruit stores or butchers. [It] reminded me that I can go to Kensington Market and do that, so I go to Kensington Market a lot more [now]…"

Similarly, two participants commented that the breadth of places (familiar and unfamiliar) they were able to discover through the application inspired then to get back into a routine. Participant S1 is an avid reader, but he indicated that this activity had fallen by the wayside recently:

"I'm a big person on reading. So I usually check out the library, but I don't go to the library as often as I used to in the past, and I would like to get back into that."

He entered *visit the library* as an activity, since he associates the library with reading books. The majority of places discovered for this activity were *"not new libraries"*, but given his reasoning the places do not need to be new, but rather reminders of reading. Participant T3 discussed that since he moved to Toronto (2 years prior) he has not been to many live concerts:

"I like live music and I don't see enough of it now…I know Toronto has a really good [music] scene…I'm hoping by suggesting places it'll encourage me to…do more of that."

In the exit interview, T3 discussed that although his intent was to go see more live concerts, he had yet to get back into the routine, *"[it] increased my awareness of concert venues in my city, and made me more aware of how few concerts I go to nowadays, which has in turn made me eager to get back into the habit of seeing live music more regularly."*

Whether the participant was looking to break out of a routine or get back into a routine, the abundance of places they were able to gradually discover with the application acted as opportunistic reminders of their desire. The continuous discovery of places ensured that the reminder was not a one-off, but rather repeated for the duration of the activity. In the case of participant T3, the application did not help him get back into a concert routine, but it did make him more aware of how important this routine is to him.

Behaviour: Assist in Choosing an Activity

One participant (S6) revealed that the application was not only useful for discovering places to perform his activities, but based on the relative distance of places (from his location) the application helped him choose what to have for lunch. S6 entered *eat pizza*, *eat sushi* and *eat tofu* into his activity list at the same time; three activities for food he enjoys eating. He would use the application at lunchtime to help him choose what he will eat for lunch that day:

"It was a good way for me to not have to come up with ideas for places to go or eat. I would take a look at it. It would say pizza or sushi or tofu and based on wherever it told me then that is what I'm going to eat that day."

Whichever activity had the closest place would be where he would eat lunch. This novel use of the application assisted S6 by using distance to make a decision for him.

Behaviour: Advocating for a Place of Activity

It was a common sentiment that adding a place for an activity required too much effort. Even still, four participants did add 25 new places into the *ActivityService* (*M*=2.1, *SD*=4.2, *min*=0, *max*=14) with participant S8 adding more than half (14/25; 56.0%). In the exit interview, he commented that his intent was to disseminate knowledge for a cause he supports—worker owned businesses:

"The point of this [activity] was…to add my own knowledge to the database. I've worked for worker owned business and I support them...it is something uncommon but for someone who is new in town then they might want to [know]."

S8 did not add *support worker owned businesses* to discover places, or add a single place he liked; he was advocating for a cause by adding a collection of places. The application supported his behaviour, and through his action he was able to associate new meaning with places that others who also support worker owned businesses may find useful.

Activity, Place and Expectations

When participants entered an activity it was often the case that they had a type or quality of place in mind where they would like to perform the activity. The majority (8) of participants commented that the places disclosed for one or more of their activities, albeit *"technically correct"* did not fit what they had envisioned. For example, participant T1 was looking to discover places to *play soccer* and one of the places he recalled the application discovered was a small inner city park called Trinity Bellwoods Park. He commented in the exit interview that *"… you can play soccer here, but it is not a soccer place. [I] was more thinking a pickup type place where you can join a game."*

Similarly, participant S1 sought to discover places where he could *withdraw money* and *deposit money*: He recalled an experience with a new place discovered by the application:

"I needed money one day…I was able to locate an ATM perfectly fine… it's not like [a] major bank's ATM, it's more one of those ATMs that are located within stores or supermarkets. I kind of wanted more of a bank institution versus…one of those stand-[alone] ATMs."

The application did help T1 and S1 discover new places to perform activities, but in both instances the place did not match their expectations. Participant S9 commented that for *buy a book* the majority of places the application discovered were libraries, "*while completely accurate… libraries [are]…not what I would consider a traditional place to buy a book…I think it leads people to think about [places and activities] they wouldn't normally think about."* It may be the case that he can buy a book at one of the libraries, but the fact that he was presented with libraries made him think more generically about places where he could get a book, not just *buy a book*. Similar to how the application helped some participants associate new activities with an already familiar place, the mismatch between expectations and discovered places can lead to a reevaluation the activity's intent and how it relates to different places.

A Place can Have Many Meanings

The application was not developed to accentuate the fact that a place can have multiple meanings. Three participants commented on the importance of being able to explore the intersection of activities and places. Participant S9 commented on how he entered *sit in the sun* and *sit in the park* in an attempt to see how the activities are related:

"I wanted to see how much they would overlap…'sit in the sun' turned up the car wash, 'sit in the park' did not. It did a great job in differentiating the intent of the activity. Being able to combine activities 'wash my car' and 'sit in the sun' and have it look at the intersection of those two and return that set of results, that would be supremely useful. Then I can choose the car wash not only on the location…but I can park my butt in the sun and bake while my car is baking."

Participant S9 had to enter both activities separately because the application does not handle conditional operators (*e.g.,* OR, AND). Similarly, participant S4 tried to apply the *OR* operation with *buy records or music*, highlighting the importance of this functionality.

Recalling Place Names

It was difficult for all 12 participants to recall the names of places discovered by the application. In the weekly and exit interview, participants commonly recalled a place in terms of its space (*e.g.,* a street name or neighbourhood): *"…there's one in Chinatown and there's another right outside Chinatown."* When we asked participant S5 to list places the application discovered for *get a coffee*, he commented that *"… if I go to Bell there are places I can get a coffee … in the area."* He added that he is able to recall the activity for the *"… area rather than specific spots in the area."* It was not that their spatial knowledge grew to include a specific place; rather they were able to associate new meaning with a space—a space that can serve as a cognitive anchor around which spatial knowledge will develop [6].

The Depth of Meaning for a Place

The majority of participants (11) did mark at least one place as wrong for the associated activity (*M*=16.3, *SD*=13.7, *min*=0, *max*=37). A total of 195 places were marked as wrong. Despite the ease with which a place could be indicated as wrong (in contrast to adding a place), participants were hesitant to mark a place as wrong unless they were completely sure the activity was wrong for the place. Unless the participant was intimately acquainted with a place, as discussed by S1, it was difficult to know the types of activities a place can support only by its name:

"I think San Francisco is well known for the mom and pop shops…and I have absolutely no idea what they are. I mean…in order to find out what XYZ shop is, I have to actually go in there. It's not like Wal-Mart [or] Walgreens where it's pretty obvious…"

Participant S13 commented that even after experiencing a space her understanding of the space may not include *"... other [activities] that another individual had experienced there"* and that some activities may not seem appropriate for a place, but it is *"possible they might have like a weekly or monthly meeting or something that I don't know about."* Participants were able to recognize that the activities that can be performed in a place are not restricted to only their experience and that activities are not always obvious.

Sharing Activities and Places

The primary usage of the application was personal, but in several instances it was advantageous for the participant to share a place with a partner or friend. Participant S13 shared the location of the Embarcadero YMCA with her partner so her partner could *go swimming*, but she also shared the location of a place to *buy Polaroid film*, so her partner could perform the activity for her:

"I know you will be rolling through this neighbourhood a little bit later. Here is this sort of place that it says I can…we can buy Polaroid film. It you get a minute, stop by and see if there is Polaroid film. I can't remember the name of the place in the Castro because, I, you know, rely on the application to keep this information for me. I texted her the address…I would know her route and I would say, hey it pointed me to this spot. I have to go this way, if you get a minute check this place out…We do [this] a lot…I hear of a place and I'm not near the neighbourhood so we would send each other to check it out."

Some activities do not need to be performed personally—the end result of the activity is more important than the experience. If an individual cannot perform an activity in their current space, it is possible that her social network (including weak ties) may be more opportunistically positioned to perform the activity for the individual. However, leveraging these people requires knowledge not only of their current location, but routes they frequently travel, and the ability to alert the person they can assist.

DISCUSSION AND OPPORTUNITIES

The results emphasize the utility of using activities and continuous search to assist in the acquisition of spatial knowledge and meaning. In this section, we distill the salient findings, and implicitly discuss research and design opportunities for technology that assists spatial behaviour.

Rethinking the Value of a Place

Participants were able to discover new places to perform their activities within familiar spaces and associate new activities with already familiar places. However, we observed that some places—albeit technically correct for the activity—did not match the participants' expectations. The mismatch between expectations and discovery meant that some places were not useful, but in some cases it led the participants *"to think about [places and activities] they wouldn't normally think about."* In the case of S9, he was looking for places to *buy a book* and the application discovered libraries. The libraries did not match his expectations, but made S9 think more generally about places where he could *get* a book, not just *buy* a book. Similar to how participants found new meaning in familiar places, places that are counter to expectations can lead people to reevaluate the intent of an activity and how a place relates to that intent.

Opportunistic Behaviour Needs Knowledge before Action

The continuous search functionality of the application and the persistence of discovered places ensured that participants did not have to actively search for places in every space they visited. Rather, they could quickly glance at their mobile phone to determine the opportunities their current space offers and prior opportunities in the spaces they had visited. Participants reported minimal behaviour change; however, the majority of activities reflected the participant's casual interest which did not necessarily need to be performed within the 4-weeks of the deployment. Participants commented that although they did not go to many of the places, the places are *"now on [their] radar"* for when it is convenient or the need arises. When participants did report behaviour changes, the changes were opportunistic. They leveraged the activities and the places discovered as opportunistic reminders of a routine they wished to break out of, a routine they wished to get back into, and as to assist in the decision making process.

The Meaning of a Place can be Ambiguous

Many of the places the *ActivityService* discovered for an activity were false positives. We did not attempt to identify and remove false positives because they will always occur on some level and we wanted to explore their influence. Participants did recognize the value of indicating a place as *wrong*, but they were cautious to do so because they were uncertain of a place's meaning. Inversely, if they were unsure if the activity was wrong, they would be equally uncertain the activity is correct. The meaning of a place is defined by the individual's experience with the place [1, 10, 14] and with activities that are conditional [19] the meaning of space may not be obvious; even when the individual is in the space. The inability to associate meaning with a place and trust in this meaning can have a negative impact on an individual's cognitive map: she could learn a wrong place believing it is correct, or dismiss a correct place believing it is wrong. However, ambiguous and erroneous places can be leveraged to suggest alternate activities an individual may find interesting and help her discover meaning in spaces she may not think to look, or look for.

Activities can be Related Spatially and Temporally

Participants often defined a single intent as multiple activities, primarily because they were unsure if the activity they entered was *"working right."* The problem with multiple entries is that it made the activity list longer and depending on the places discovered the activities were not always proximally close in the listing. The application needed to support this behaviour providing the ability to associate activities and highlight the similarity and differences between activities. Knowing how an activity, or

multiple activities relate to one another can allow for better places to be chosen (*e.g.,* a place where the person can perform multiple activities) or places that are proximally close so multiple activities can be performed in sequence.

CONCLUSION

Spatial knowledge and meaning is not innate; it is gradually acquired with repeated experiences with a space [5, 16, 18, 21]. In this work, we presented Opportunities Exist, a context-aware place discovery application that differs from traditional on-demand search (*e.g.,* Google Maps) because place discovery is achieved using a simple expression of activity (*i.e.,* drink coffee, sit in the sun, smell baking bread). In addition, the application continues the discovery process as the user goes about her day—retaining a history of places that she can reflect upon. We conducted a 4-week deployment in two North American cities to evaluate Opportunities Exist. The results show that participants were able to discover new places in familiar spaces to perform their activities and learned to associate new activities with familiar places—activities they did not previous know could be performed at these places. Use of the application led to the opportunistic performance of activities, and continual place discovery was used to provide opportunistic reminders and awareness of routines the participants wished to break or resume, and to assist in their decision making process.

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