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Uncover

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TITLE

Uncover: Supporting City Exploration with Egocentric Visualizations of Location-based Content

ABSTRACT

This paper describes the design and evaluation of Uncover: a mobile application that supports users in exploratory pedestrian behavior to gain situational awareness of their immediate environment. The design was based on guidelines derived from foraging theory and relies on egocentric views, which keep the virtual content automatically aligned with the real world. We carried out two studies with Uncover, which examine the successfulness of design choices aiming to support tourists' city exploration while interfering with experiencing the surroundings as little as possible. A lab study tested the effect of different marker and background types on the time to recognize the direction with most content. The designs performing best were implemented in the final prototype, and a field study analyzed the exploration behavior tourists and visitors exhibited while using it. The study showed that supporting the exploration can be improved by enabling features that are either disabled by default or not available at all in commercial map applications, like egocentric orientation of the map, providing images of venues just by pointing to their direction, and displaying clusters of several venue types.

KEYWORDS

City exploration, exploratory navigation, location-based content, field study, foraging theory, design

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1. INTRODUCTION

There were over 1.2 billion international tourist arrivals worldwide in 2016, an increase of 3.9% from the previous year [1]. Building tools that effectively support this huge and growing user group is a great opportunity for both tourism industry and mobile application developers. Tourists are, by definition, on the move and in environments unfamiliar to them, so they need tools to support their wayfinding.

Allen [2] has divided wayfinding tasks to three categories: travel with the goal of reaching a familiar destination, travel with the goal of reaching a novel destination, and exploratory travel with the goal of returning to a familiar point of origin. Mobile navigation applications typically focus on reaching novel destinations efficiently, which is a valid need for tourists. However, Brown [3] and Brown et al. [4] discovered that tourists often do not want to create explicit route plans, but rather head in the roughly correct direction and make detours at will. Furthermore, previous work found that tourists switch fluidly between traveling to novel destinations and exploratory travel, reacting dynamically to the opportunities they see around them [5]. For them, reaching a specific destination is usually not the ultimate goal of their wayfinding. The goal could just be experiencing the most atmospheric parts of the city. Tourists may, for example, switch from navigating towards a particular church to exploring the streets by the seafront when seeing a glimpse of the sea on the way.

Google Maps and other popular commercial navigation applications allow searching points-of-interest (POIs), like restaurants, and display the best matches on the map to support choosing one. The visualizations focus on one category of venues (cafés, museums etc.) at a time. Their focus is on deciding a single POI to visit, but are not designed for conveying the atmosphere of an area, or finding the nicest neighborhoods to explore. Several research systems provide eyes-free navigation support in order to make it easier to pay attention to interesting things on the way to a specific destination e.g. [6–9]. However, they do not support the actual exploration where the tourist is looking for clues as to where to walk to experience the nicest views, for example. Their evaluations have also focused on the success of finding the destination, rather than the experience of exploring one's surroundings on the way. Since their focus has been on general pedestrian navigation, very few of them have been tested with tourists or visitors as participants, who would have explored an area they were genuinely interested about. As exploring is very much internally motivated, this leaves room for further work focusing on the experience of exploring an area with the support of mobile application.

In this paper, we address these issues through the evaluation of Uncover, a mobile application providing hints on which direction to choose when exploring streets of a city. It is aimed to be used during exploration and is optimized for the needs that tourists have during that activity. To only minimally interfere with the exploration and let people focus on their surroundings, we designed views providing simplified overviews of nearby area from the viewpoint of the user, and evaluated them in a lab study. For the field study, we recruited tourists and recently arrived visitors, and asked them to try the application at an area they were interested to explore. The study showed that supporting the exploration can be improved by enabling features that are either disabled by default or not available at all in commercial map applications, like egocentric orientation of the map, providing images of venues just by pointing to their direction, and displaying clusters of several venue types.

2. RELATED WORK

The existing literature supports understanding exploration as an activity, and systems that could support exploration have been developed by the HCI community. Some of them approach it from the angle of navigation e.g. [6, 7, 10], others aim to increase one's understanding of the surrounding environment e.g. [11–13]. This section summarizes this literature.

2.1. Exploration

Allen [2] has categorized navigation tasks, and he makes a distinction between travel with the goal of reaching a familiar destination, travel with the goal of reaching a novel destination, and exploratory travel with the goal of returning the origin. In exploratory travel, the focus of the activity is on discovering new things in areas one passes through, while in the other forms the focus is just to reach the destination.

One can find a parallel to exploratory travel from the field of exploratory information search. When searching for scientific documents for example, people start with a tentative query and selectively seek information from documents and obtain cues where to continue next [14]. Similarly, in the case of exploratory travel, various means can be used but, according to Allen [2], in cases where the area is unfamiliar to the person, oriented search and piloting between landmarks are most suitable. When relying on oriented search, the traveler orients with the perceptual (often visual) information and just keeps on searching until the goal is achieved. In piloting, the traveler selects landmarks from the environment and associates direction and distance information to them to keep oneself

oriented. Both means of exploratory travel require scanning visual details of the environment and making decisions based on them, as in the case of information search.

2.2. Foraging theory

Animal food searching behavior is analogous to both exploratory travel and exploratory information search. The animal needs to decide when the area has become depleted and costs of searching for food from the current surroundings exceed the value it generates, so the animal will move to a new area to maximize the value it gets [15]. The animal benefits most if it is able to choose areas, which on average provide most food with least effort. This has been modeled with foraging theory and multiple models to predict the time to leave the patch or change the diet have been created [15].

Foraging theory has been applied to exploratory information search as information foraging, which considers the relation of value gained and effort spent in finding the items that provide the value [16]. Similarly, in tourists' exploratory travel the decision to leave an area requires considering the effort needed to find more interesting places from the current area, the effort to move to a new area, and the expected interestingness of the new the area. In our previous study, we observed tourists' exploration and saw that, when the time was limited and area large, people started to weight the gains of exploring the city further against the effort of having to rush to their next engagement, exactly as foraging theory predicts [5]. As in the case of information search, foraging theory could be used to inform the design of the tools for exploratory travel, but so far examples of this are missing from the literature.

2.3. Prior Research on Systems Supporting Exploratory Travel

People have a capacity to process visual information extremely efficiently [17], so one approach for aiding exploratory travel is to present supporting information visually. Block Party by Zhou et al. [10] is an application for planning multi-point routes and displaying the waypoints on a map, in an augmented reality (AR) layer over the camera, and as a list. By allowing the participants to freely switch between the views when inspecting each waypoint, the authors aimed to support goal-driven expeditions, which they describe as the middle ground between free exploration and strict planning. In the field study, participants were exploring neighborhoods by following an itinerary of generic destinations (a bank, dentist etc.) provided by the researchers, so the focus was on keeping the sessions comparable. This also meant that spontaneous exploration was not observed, which leaves room for further work on the area. Field study participants got lost on average two times per session and commented that mentally rotating the map, which stayed in a north-up orientation, was difficult and error-prone. The participants coped with this by physically rotating the device, but to further help with the issue in future applications, Zhou et al. [10] suggest implementing egocentric views, which keep the content aligned with the user's current view of the real world. Egocentric orientation was also the most popular mode for a pedestrian navigation task in a study by Wen et al. [18], where participants were given an option to switch between north-up and egocentric maps, as well as compass, radar and AR views. The authors identified several navigation styles, but three out of four groups used egocentric map more than the north-up version.

The most popular commercial applications, like Google Maps, rely on the combination of visual and spoken information. They allow searching POIs, like restaurants, and display the best matches on the map to support choosing one. In addition, they calculate the shortest route to the POI and provide a navigation-focused mode, which highlights the turns one needs to take. The directions are presented both on the display and, when approaching them, as spoken prompts. Zhou et al. [10] studied the use of Google Maps for neighborhood expedition task. The participants were asked to find POIs to visit, create routes, and walk the routes. The authors observed that serendipitous activities, like seeing something worth visiting later and saving the POI, interrupted the navigation. Resuming the navigation required starting the task from the beginning.

In our previous study, we observed tourists using existing commercial tools, including Google Maps, during a city visit [5]. It revealed clear phases, even though participants moved flexibly between them. First, one had to decide the next destination to visit, which involved web searches and checking from Google Maps how far the potential destinations were. Then, Google Maps provided navigation directions, which helped finding the destination but orienting them with the real world was cognitively demanding. When getting the destination in view, or spotting something intriguing on the way, the participants put the phone away and transitioned to exploring, which was more relaxed and guided by what happened to catch their attention in the real world. Maps became useful again when they started considering their constraints, for example that they have to catch a bus at certain time from certain location and had to decide when to stop the exploration. Both studies highlight that the design of Google Maps supports visiting single POIs reasonably well but is not optimized for exploring areas.

Many existing research systems for supporting exploration of cities have been built from a different viewpoint, which focuses on providing eyes-free navigation support for people who have a definable destination they want to

visit. For example, AudioGPS [6] and ONTRACK [7] present sound, and Navigation Your Way [9] provides vibration, that appears to come from the general direction of the destination the users have defined. Therefore, users do not need to pay attention to the device display and they can focus on their surroundings during navigation. Similarly, SoNav presents audio feedback to guide the users back to a route if they decide to explore something on the way [8]. In Allen's [2] terms, these systems help users aiming to reach novel destinations but since they assume that the user specifies the destination one wishes to visit before starting the travel they do not focus on the kind of exploration where the user just wants to discover what is around him or her.

Detailed route plans do not fit free exploration, but some work on reaching a specific destination might help experiencing pleasurable parts of a city when the user is traveling to a definable destination. Quercia et al. [19] crowdsourced perceptions of locations, and El Ali et al. [20] identified areas where tourists take many photos, to help the user to plan a route that is not only efficient but stimulating and pleasant as well. Experiencing the most pleasant parts of the city might be the underlying goal for most of the activities tourists do [5] so, for cases where the plan is to reach a specific novel destination, these systems could provide substantial additional value.

Even though systems like Block Party, AudioGPS and ONTRACK have been built to reduce the effort to find venues, their evaluations have not concentrated on the exploratory behavior these systems generate [6–10]. Since the focus has been on the navigation, the participants have fulfilled tasks that researchers have given them and have not been exploring areas to satisfy their curiosity. This leaves room for further work on studying how mobile applications could support exploration.

2.4. Location-based Content

Another approach for supporting exploration is increasing one's understanding of the surrounding environment. Any digital content can be assigned with a real-world location representing how it relates to the physical environment [21]. Smartphones geotag photographs and location-based social networks, like Foursquare/Swarm, let people check-in to POIs, i.e. confirm their presence at a certain location [22]. They also allow commenting POIs, i.e. effectively assigning a location to the comments one shares with other users.

In terms of foraging theory [15], visualizations of location-based digital content could be used to support the users' assessment of the value they might get from exploring certain locations, helping them to make choices while exploring streets. To provide basic understanding of things around the user, already the classic location-aware prototypes for visitors, like Cyberguide [11] and Lancaster GUIDE [23], visualize information about nearby POIs. Serendipitous City Guide [24], on the other hand, provides tactile alerts when the user approaches any of the locations he or she has indicated wanting to see. The system also warns when the user is moving away from a POI to help locate it. Roaring Navigator [25] plays directional audio from nearest landmarks in a zoo. Exploratory mode plays the sounds from the nearest POIs to extend the understanding of one's surroundings, and navigational mode plays audio from the specific destination the user intended to reach, similarly as the prototypes described in the previous section. All these systems increase awareness of nearby POIs but the interests of tourists during exploration are wider than individual venues, covering pleasurable views and all the things that define the local culture in the area, like local habits and specialties, as well as the distinctive architecture [5].

User-generated content such as comments and images can indicate something about the local culture and the atmosphere of a place. Classic systems such as GeoNotes [26] and E-Graffiti [27] let people create and read textual notes, and later ones such as InfoRadar [28] both text and images, attached to real world places. These systems are focused on the social interaction these features enabled, and not on how they support exploring physical space. Partly this is explained by GeoNotes [29] and E-Graffiti [27] relying on the use of laptops in the field studies, which restricted the usage during the actual exploration, leaving room for more research to support the design of tools for exploration. Navigation Your Way [30], discussed in the previous section, included simulations of a concept that would provide vibration feedback about location-based social media content when scanning the environment by pointing with a device. However, neither the exploration behavior, or the experience this generates, were not studied with actual participants.

Systems indicating popularity of POIs, such as Hot City [12] could provide hints on interesting areas to explore. Hot City displays the number of people present in a venue as an icon on the map on an interactive public display. One can filter based on venue category, but the icons are same regardless of the category and the name of the venue has been omitted from the interface. When studying the use of it, researchers found out that the amount of preview of the POI (like the category and name) available is important for deciding if the POI is worth examining further. Similarly, Just-for-Us by Kjeldskov & Paay [31] visualizes the activities people are engaging in, like eating or having coffee, on different parts of a public square to provide cues for what to do and where to go. In a user study, participants used this information for opposite purposes: some wanted to check the popular places out, some chose

to avoid places with too many people [32]. More generally, linking digital content with live data from real world gives people helpful tools to direct their real-world exploration activity.

More orchestrated location-based experiences have been built as well, which still aim to entice exploration and increase the curiosity towards one's surroundings. Ambient Wood Journals seeks to educate children by providing information about plants and animals in their proximity as they explore a forest [33]. The content depends on the locations and content they have already experienced. SHARC is a more recent framework that encompasses tools for, for example, historians to place location-based content to an area and build an educational experience for people visiting it [13]. Visitors can also contribute by adding new locations and content but publishing it requires approval by a historian curating the content.

Ambient Wood Journals includes game-like interaction with the virtual content where the children can introduce changes to the habitat, like flooding the forest, which then affects the virtual content they are experiencing [33]. Some pervasive games have taken interaction and orchestration further by introducing a more elaborate story where the user's interaction with the virtual content allows revealing more of the story and advancing in the game. For example, REXplorer introduces virtual spirits who tell stories of historic events when the user casts spells at right locations [34]. TimeWarp, on the other hand, places time portals around the city where users can see virtual content describing the area during different time periods, while solving the mystery of the disappearance of the city elves [35]. Both REXplorer and Ambient Wood Journals provide a record of the user's activities in the end, to support reflecting what one experienced [33, 34].

A number of systems have been built to provide content that describe venues, but their evaluations have not concentrated on the exploratory behavior these systems generate [13, 23, 24, 26, 27, 33–35]. Since the focus has been on the game design [33–35], social interaction emerging while using the systems [26–29, 32], or the systems have not been particularly mobile [12, 26, 27], the exploration behavior has not been described. As the issues related to how mobile applications could support exploration remain unaddressed, there is an opportunity for further work on the area.

2.5. Derived Guidelines from Related Work

The remaining sections address the identified gaps and describe the design of an application that supports the exploration activity with readily available information about the surroundings, and a study of the exploration behavior that emerged when using it. The participants were exploring areas guided by their curiosity and no specific destinations were set by the researchers beforehand. Foraging theory was used to guide the design of the application.

We based the design on the findings of our previous study [5], which suggested that tourists value pleasurable views and distinctive architecture during exploration. To support them, we decided to provide rich previews of the surrounding areas, as these have been found to be important [12]. Furthermore, we used foraging theory to provide guidelines for the application design. It suggests that, to be able to assess the potential value users might gain by moving to a new area, they need effortless ways to identify patches of content that provide value to them. They also need to be able to compare available patches both regarding the richness of valuable content and the effort needed to reach them [15]. Our previous study [5] also suggests that with existing commercial tools selecting the next destination involves web searches, and navigating to it can be tedious and cognitively demanding. In our work, we wanted to make those phases feel more like exploration. Since the main activity during exploration is experiencing the surroundings, we aimed to provide the support in a way that only minimally interferes with it. To achieve that, egocentric views were designed, as previous research suggests [10, 18].

3. PROTOTYPE DESIGN AND RATIONALE

In this section, we present the design of Uncover, a mobile application providing hints on which direction to choose when exploring streets of a city. Compared to existing commercial systems, the design aims to make choosing the direction less like searching and more like exploration. Much of the previous work has relied on audio or haptics to present feedback. We chose to use visual feedback to benefit from human capacity to process visual information extremely efficiently [17], and chose to study minimizing the interference by designing views that require minimal interaction with the device. We optimized for example the number of taps (i.e. input), as well as the time and mental effort needed to process the visual feedback (i.e. output) from the system. To achieve that we experimented with different ways to simplify the views and streamline the interaction.

Based on foraging theory, we wanted to provide means to assess the potential value one might gain from visiting an area. Therefore, the starting point of the design was visualizing the location of different type of venues in relation to user's position. While the individual venues will reveal only limited aspects about the area, displaying all venues of certain type in an area can suggest something more. According to foraging theory, the areas that contain large

amount of promising venues that are accessible with low effort should interest the user. Additionally, just seeing an area with many historical buildings can give an idea of the architecture and atmosphere of that area, for example. Still, to be able to make reliable and quick decisions regarding the venues, the user needs rich previews of his or her options effortlessly. For that, images of venues were provided just by pointing the device to the direction of the area.

3.1. Main View with Venue Icons

To provide an idea of the value the areas might provide, the main view consists of map and radar representations of the locations of four types of venues: cafés, historical buildings, shopping centers, as well as parks and outdoors (see Fig. 1). Switching between map and radar happens with a button on the top-right of the view. The amount of venue categories shown can be controlled by tapping the drawer icon on the top left and selecting them on a list.

The map contains important details about the environment but combined with a lot of markers the view can become quite cluttered. In case of typical grid plan in a city, just showing the venue icons might already provide enough information. To further help make the options the user has as explicit as possible in the typical grid plan, a radar pattern that divides the area to four quadrants can stress which venues lie to the left of the user, for example (see Figure 1). The rings in the radar pattern also make estimating the distance (i.e. effort needed to get there) straightforward if the scale is easy to grasp, so Uncover used scale of 1 km (about 15 min walking distance) from the center to the outer ring.

To minimize the mental effort required to orient the information with the real world, the application was designed to rotate the visualization to match the user's view all the time (i.e. egocentric, or forward-up orientation). The venues that are ahead of the user are always on top of the display, not the ones north of the user (i.e. north-up orientation), as is more common in map applications. North-up has been shown to minimize disorientation during a pure navigation task, provided that the users manually keep the device pointing north by rotating it as they turn [36]. However, manually tracking where the north is would detract from the exploration, and it has been shown to lead to many navigation errors in the exploration context [10], so we decided to keep the virtual and real information aligned automatically. As exploration is very dynamic activity where one's focus is constantly directed to new things, the applications supporting it should be in sync with the user's current focus whenever possible.

Fig. 1 Venue icons on a map (left) and radar (right)

3.2. Image-based Overview

As described above, we wanted to provide richer previews of the venues than just markers depicting the type of the venue. We also aimed to help users find areas with distinctive architecture and pleasant views, and images could support both goals. For example, a group of images from an area helps users to quickly grasp whether the area has many seafront attractions (see the right image in Fig. 2).

Since placing the images of venues spatially on a map or radar would have required so small thumbnails that they would have been difficult to recognize, we placed the venue images on a grid the user can pull from the bottom of the screen. Rotating the phone updates the images on the grid so that they always depict the venues that lie ahead of the user, matching with the egocentric orientation of the rest of the application (see Fig. 2). Tapping an image

highlights the corresponding venue marker and vice versa. The border of each image has the same color as the venue icon to make the type of the venue immediately obvious without tapping it. The image grid can be pulled either half-way to see 6 images at a time, or full screen to get 15 images. Automatically updating images on the grid provides a visual overview of the direction one is interested about just by pointing the phone to it, similarly as augmented reality does, but this solution reduces the details displayed on the screen, which was our design aim. In addition, it allows using wider field-of-view and more uniform grid layout for presenting the images, and it does not require holding the phone at eye-level.

Fig. 2 Both radar and images update when the phone is rotated 90 degrees counterclockwise. Quick glance on the images conveys the different type of views provided by the areas the phone is pointing to. The one on the left has a concentration of cafés, the one on the right offers several outdoors and seafront attractions.

3.3. Comparison to Commercial Systems and Related Work

The map view of the Uncover prototype resembles popular map applications like Google Maps visually and offers some similar features. However, the deviations to them are important for exploration. Image-based overview is offered, and updated automatically as the user turns (see Fig. 2), which, in terms of foraging theory, provides a quick glance of the potential value of a particular direction. As exploration is a dynamic activity, offering this without the requirement to tap through the options one-by-one is key for minimally interfering with the actual city exploration. Automatically rotating the map and radar to provide an egocentric overview of the environment keeps them in sync with the image-based overview and removes the need to mentally rotate the view to match with one's orientation. Lastly, displaying the clusters and not hiding them, as it is usually done to deal clutter of multiple markers [37], allows users to immediately identify areas that could provide most value with least effort, which according to foraging theory [15] makes them optimal candidates for a visit.

Compared to eyes-free navigation systems described in the literature, Uncover puts less focus on guiding the user to a previously set destination. Instead, it aims to provide an overview of what is around, and support the actual exploration activity i.e. choosing the direction to go dynamically based on the information available at any moment.

4. PILOT STUDY

When several markers are placed close to each other, the resulting clutter is often considered an issue that has to be dealt by hiding some, or by replacing multiple markers with an aggregated representation, both of which can make the area stand out less [37]. As described in the previous section, we wanted to let large numbers of markers convey higher-level information about the nature of the area, so neither of these were an option but we did want to experiment with the marker designs, and other ways to reduce the amount of details presented on the screen. For this, we designed a lab study concentrating just on the venue markers and background graphics, and left the evaluation of the image-based preview for a field study described in Section 5.

Markers can be abstract and let people create their own meanings, or they can have more details and attempt to create an association with the thing it represents [38]. From the abstract end, we chose to experiment with plain single-color dots, which form larger continuous areas when many venues are close by. They reduce the clutter when forming clusters while the larger composite markers still naturally catch the user's attention (see bottom row in Fig. 3). On the other hand, the meaning of a well-designed associative marker is more obvious to catch than a color,

which could affect the time users need to process the feedback. To know which of the effects is stronger in our case, we experimented with both arbitrary dots and associative icons of the venue types.

The amount of details shown behind the markers might affect the time needed to grasp the meaning of the representation if the background is too similar to the markers [39]. To see if we can help users to detect the areas they are interested about faster and therefore interfere less with their experience of surroundings, we tested the effect of simplifying the map graphics. Three versions of a background behind the icons was tested: basic Google Maps graphics, radar graphics showing no details about the environment, and completely empty black background (see Fig. 3).

Fig. 3 One example point pattern using 2 venue types with all the marker-background combinations considered in the initial design phase. Top row from left: icon-map, icon-radar and icon-empty. Bottom row: dot-map, dot-radar and dot-empty.

To narrow down the design options and confirm that the design allows reaching the decision with minimal effort, we started with a lab study. Restricting the task and controlling the environment helped to concentrate on how the design options affected the time needed to detect the areas that have a lot of potentially interesting content. On the other hand, tests in the lab environment do not sufficiently highlight all the relevant aspects of a system designed to support city exploration so, in the second phase, we completed a field study, which will be described in Section 5.

4.1. Method

To test the effect of the marker and background designs, 42 random point patterns (and 6 for practice tasks) were generated using spatstat package and rMatClust (stationary Matern’s cluster process) function in R [40]. The resulting patterns contained 60 points of interest in one or more clusters of points that visually resembled clusters of nearby venues within a 15 minute walking distance in central Helsinki (where the second phase field study was run). The number of venue types in each pattern varied from 2 to 4, with each type represented by the same icon and color. The patterns were divided into two blocks to test the effect of learning. The same patterns were used with all marker-background combinations (see Fig. 3) but were randomly presented.

18 participants (all students (11 males, 7 females, avg. age 28) took part in the pilot study. All had normal, or corrected to normal, vision. The images were shown one at a time on a desktop display connected to a Mac (see Fig. 4). The image size on the display screen was adjusted to provide similar retinal image size as a phone that is held at 40 cm distance from the eye. The participant’s task was to choose which direction (north, northeast, east, southeast etc.) had the most venues of certain type. According to foraging theory, that direction should provide most

value with least effort so it should be the most promising direction to choose when exploring city streets. The participant pressed a corresponding number key on a numeric keypad, which were labeled with arrows to reduce visual search on the keypad. Presenting the images, as well as recording the task completion times and the actual key pressed, was handled by PsychoPy [41] software.

Fig. 4 An example of a visual stimulus used in the study (some of the empty space around the user interface graphics have been cropped to make the image easier to read)

Participants completed each marker-background combination. Between each condition, the participant completed a short questionnaire by scoring statements on a 7-point Likert scale. The order the marker-background combinations were presented for each participant were balanced for carryover effects using balanced Latin squares.

4.2. Results

The 18 participants carried out 252 tasks and 36 practice tasks each, divided to six marker-background combinations. To assess the time the user needs to gaze at the screen, the average and median task times were calculated. The median of all task times was 2.24 s and 85% of tasks were finished in less than 4 s (see Fig. 5). 4-way repeated-measures ANOVA with marker type, background, number of venue categories and block as independent variables was carried out and Mauchly's test confirmed the assumption of sphericity for all of them. There was a significant main effect for marker type where icons resulted in significantly shorter task times than dots (2.68 s vs. 2.95 s, $p=0.004$, $F(1, 17)=11.241$). Background type did not produce significant effect on task times: map 2.72 s, radar 2.89 s, and empty 2.83 s ($p=0.762$, $F(2, 34)=0.274$). There was a significant main effect for block where second block was significantly faster than the first ($p=0.001$, $F(1, 17)=14.36$) but the effect was similar both for icons and dots as none of interactions were significant. Furthermore, none of the effects on the number of errors made were significant.

Fig. 5 Histogram of all task times from all participants

Questionnaire data revealed that there was a significant effect on how easy participants considered the information was to locate (Friedman, $p=0.032$, $\chi^2(5) = 12.184$). Icon-radar was rated to provide information significantly easier than the dot-empty (Wilcoxon, $p=0.03$) while difference to map versions were not significant. There was also significant effect on how visually pleasing participants perceived the different options (Friedman, $p<0.001$, $\chi^2(5) = 26.304$). Icon-map was perceived significantly more pleasing than dot-radar (Wilcoxon, $p=0.015$), and dot-empty (Wilcoxon, $p=0.005$). All Wilcoxon p -values have been Bonferroni corrected for multiple pairwise comparisons.

Comments explained that the radar was considered helpful but visually unpolished, partly because the extreme contrast of black and white. Many commented that the map is sometimes needed in a real use situation since it can reveal obstacles that are not obvious from the radar alone.

In general, task times (median 2.24 s, as described above) were quite acceptable for an application aiming to minimize the time spent looking at the display. As to explaining why tasks with icons were faster than with dots, participants commented that dots made them check the legend more often than icons. Regarding the background options, although the higher amount of details on the map could in theory slow down the tasks, the effect, if it existed, was not large enough to become statistically significant in our data.

5. FIELD STUDY

Since Uncover was made to support exploring streets, it was important to also study the final prototype with a field study where participants use it while actually exploring some area. Furthermore, we wanted to study behavior where the users were genuinely interested to explore their surroundings and where the application was used to satisfy their own curiosity. Exploration is so strongly internally motivated that providing exact tasks or asking people to explore an area they would already know well would have contributed to forced and artificial behavior. Therefore, we recruited visitors as participants, let them choose the area we met at, and gave a very open task to just explore anything they found interesting while using the application as much or as little as they wanted. The study was organized in the center of Helsinki, Finland during the holiday season winter 2016-2017.

The method (described below) was the same as in our earlier study [5], except previously we did not provide any prototype to try out. In that study, participants were using the tools they normally had available for them, like Google Maps mobile application or paper maps. The similarity of the method allows for some informal comparisons between the behavior in these two studies, and provides data on how using Uncover differs from using the commercially available alternatives.

5.1. Tested Prototype

Based on the results of the lab study we chose icons over dots to represent POIs in the prototype for the field study as these reduced the need for checking the legend. Both map and radar were implemented to the final prototype, since in the lab study the radar was considered helpful in deciding the direction quickly, while the map can reveal obstacles (e.g. the need to cross water). Since the extreme contrast between black and white was commented negatively in the lab study, a slightly lighter background was chosen for the radar for the field study (see Fig. 1).

The Uncover prototype was implemented as an Android application using venue data from Foursquare [22]. Foursquare uses an extensive categorization scheme of hundreds of venue types and separates for example coffee shops and cafés. We chose to use only a small hand-picked subset of the Foursquare venue types to relieve participants from browsing the massive collection of the available types, and to allow us to provide broader categories combining for example cafés and coffee shops, as well as parks and gardens. Whilst Foursquare provided good coverage of most commercial venues, it did not contain much information about historical buildings in Helsinki. Therefore, this information was added manually based on data in Wikipedia. Egocentric perspective was implemented with the Android rotation vector sensor, which fuses data from accelerometer, magnetometer and gyroscope. The algorithm selecting the images to be shown on the grid prioritizes venues in the front 90-degree sector, but if there are empty spaces left, it will use images from the full 180-degree semicircle in front of the user. The location of the image in the grid persists over updates to minimize the visual noise when scanning the area with the phone.

5.2. Participants

To recruit participants who would be motivated to explore an area of Helsinki, we circulated advertisement in tourist information office, local couchsurfing Facebook groups, hotels and hostels. When the new term started at the university in January 2017, we also e-mailed our recruitment advertisement to exchange students who had just arrived. People could participate either as individual users or 2 to 3-person groups, whichever suited them best.

We recruited 17 participants (one 3-person group, three 2-person groups, and eight individual users). Ten participants were male, 7 were females. Ages varied from 18 to 67 years with the average 26.3 years. Two came from other parts of Finland, six were from other European countries, six from Asia, one from Africa, one from North America, and one from South America. Three participants had come to a short tourist visit, two worked as au pairs, ten had just arrived for international study exchange, two were studying for a degree in a university and one was visiting relatives in the city. Although six participants had visited Helsinki 4 or more times before and already knew some parts of it, all participants explored areas that were new to them.

To assess the traveling styles of participants, six statements by Beeco et al. [42] were used. Participants scored each statement from 1 (not at all important) to 7 (extremely important). For each question, a difference to the mean answer was calculated for each participant. Five participants consistently answered questions regarding planning-oriented style more than one standard deviation above the average. Three participants consistently answered exploration-oriented questions more than one standard deviation above the average. One should not make too strong conclusions from this without being able to compare with averages from larger population, but we can analyze if the amount of differences in traveling style visible in our participants have any noticeable effect on experiencing the application. The amount of standard deviation (up to 1.6 per question) also suggests that we were able to recruit a reasonably diverse group of participants in this regard, which increases the external validity of the study.

5.3. Method

When recruited, we asked participants for an area in Helsinki they would be interested to explore. We then agreed to meet in a café somewhere close to that area to start the study. The purpose of the study was explained, participants filled out consent and demographic questionnaires, and we also carried out an initial interview on participants' city exploration experiences and why they chose that particular area.

Participants were then given a Nexus 6 Android phone running Uncover, and were asked for their first impressions. Participants were then told they could choose where they want to go and the researcher will join their group but will not take part in the decisions. The researcher shadowed the group observing, collecting data and asking a few questions at key points (such as after deciding a next place to visit or making other decisions). The questions were related to participants' current activity, for instance what interested them in a particular sight. To ask the questions in a relevant context, the researcher had to be present, ruling out the option of leaving the participants to use Uncover independently. As is typical in shadowing studies (see e.g. [43]), the researcher was not trying to be a full member of the group, nor in a completely observatory role (as this would have been unnatural for the participants). The experimenter acted as a temporary travel companion of sorts, able to converse with participants, but not take part in decision making or assisting in navigation. Participants were told that they can use Uncover as much or as little as they wanted.

Uncover stored logs about each tap in the user interface (UI), and the contents of screen and audio was recorded with AZ Screen Recorder [44] application. The researcher carried a GoPro camera in a chest harness, and ran a GPS logging application on an Android phone he carried, so that the context of use became recorded as well. Since the weather in December and January was quite cold (from +4 to -8 degrees Celsius), participants were given fingerless gloves, which helped them keep their hands warm while still being able to use the touch screen accurately.

Participants explored the area and used Uncover until they felt they had seen everything they wanted to there. If participants were still continuing after about an hour, the researcher suggested to make the next destination a café or other place where the exit interview could be held. Participants completed a questionnaire and a short semi-structured interview on their experiences and use of the app. In addition, we asked participants to compare use of Uncover with their earlier experiences exploring streets without it.

The screen capture videos, context videos from GoPro, audio, and the GPS route were combined to one video for analysis. Videos were iteratively annotated to identify critical points relevant to exploration, navigation and application use. The findings were labeled and analyzed for salient themes, which will be reported below.

5.4. Results

5.4.1. Overall Use

Usage session lengths with Uncover varied considerably while the average session length was 40 minutes. Six participants spent around half an hour, whereas two participants explored over an hour. Many reasons contributed to the differences in the session lengths. If participants kept finding new things to explore and were enjoying it, there was no reason to stop the session. In two cases, participants started to feel cold and wanted to get somewhere warm around the half an hour mark. In three cases, the app was missing some features or content participants would have needed (more details below), so they felt they had exhausted the interesting content sooner. One user also had a tight time constraint preventing staying more than a half an hour.

All participants, except P6, explored the chosen area by foot. The study setup included meeting close to the area the participants were interested to explore, so there was no need to travel long distances. The distances participants covered, as reported by the GPS on the phone, varied from 1.1 to 4.8 km with the average 2.1 km. The average walking speed was 3.0 km/h, which is quite leisurely pace. P6 has been left out from these calculations, since she was in a hurry to her next engagement and travelled part of the route with a tram while still using the app.

The majority of participants reacted positively to the application. It was described to extend one's vision and make one less reliant on luck in finding places: *"When I first came I didn't know where to go so I was just walking in the street and if I'm in luck I find something. With this one I have the power to control [...] what I want to see. If something is not appealing to me, I wouldn't even go there"* (P1, Male, 26 years, Singaporean). Even though the participants had used Google Maps during their trip, they felt Uncover provided the information more readily, which fit their usage: *"It's giving you like picture of the area where you are, what is nearby. Other apps give you the name [...] With these symbols it's more practical, you can just guess what it is"* (P2, Female, 25 years, Moroccan). This resonates well with our aim to make choosing the direction to go resemble exploration more than with current systems.

The positive reaction was also apparent in answers to the statements in the final questionnaire (scale from 1: completely disagree to 7: completely agree). They were extremely positive for "The app helped me to see what was around me" (median 7, interquartile range 1.5), "The app helped me to choose the direction to go" (median 6, interquartile range 2), and "The app enriched my visit" (median 6, interquartile range 2). Three participants were less enthusiastic about the application because it was missing the kind of content which would have been important to them. One of them would have liked assistance in finding clothing stores, and another for bars, but neither of these types were shown in the application. The traveling styles of participants tested in the background questionnaire did not have a noticeable effect on the overall reaction to the application as the less enthusiastic participants were: one explore-oriented, one planning-oriented and one who was in between.

All users favored either the map or the radar (see Fig. 6), which will be discussed in more detail in the Navigation section (5.4.3) below.

Fig. 6 Four participants clearly favored the radar and spent less than 31% on map. Eight participants favored the map and spent over 72% of time with it.

Participants used Uncover for four main purposes. They looked for support in (1) deciding the next venue or area to visit, (2) navigating to the destination, (3) getting to know more about something they saw visually in the environment, and (4) getting to know the distant options visible in the application. The following sections outline the findings related to each of them.

5.4.2. Deciding a Venue or Area to Visit

Participants visited 2 to 6 venues (i.e. POIs) or areas during the session (avg. 3.3). Very much in line with typical foraging behavior, the participants first explored the options Uncover presented, then chose one of them and navigated there, and enjoyed the area for a while before starting from beginning. In 82% of the cases, reaching a decision about the destination required studying (i.e. tapping the icon or image of) just 0-2 venues. (Since the icons were visible on the map or radar all the time, some decisions were made just based on them, without any taps.) In the remaining cases, it consisted of more careful consideration of one's options and studying 5-12 venues. All participants made at least 2 decisions with 0-2 taps, and a half of the participants did at least one more carefully considered choice. In the case of 0-2 taps, participants scanned their surroundings by turning slowly and, if they spotted an image or icons in Uncover that arouse their interest, they typically checked the name and exact direction it lay, which was enough information to reach the decision. As one of the participants described a case where he chose a market hall for his next destination: *"I just saw the image and it looks quite interesting. It doesn't really look like a café."* (P7b, Male, 23 years, German). The fact that it is not entirely typical building made it stand out and he also commented that, since the building looked large, it seemed easy to find, and a place that could have more than one café (see Fig. 7). As this example reveals, many venue details that would have been arduous to implement to the prototype were implicitly available in the photos.

Fig. 7 An image of the café P7b chose to visit (photo by Marco Mäkinen)

The straightforward usage pattern involving only 0-2 taps matches well with the design objective of minimally interfering with the user's activity, although reaching the decision took on average 24 s. Even the cases with 0-2 venues tapped took in one third of the instances more than 15 s (see Fig. 8). This reveals that, in several cases, people were using comprehensively the compass functionality to scan their surroundings and assess the value different directions would provide.

Fig. 8 Histogram of time (in seconds) to decide a venue or area to visit

For example, P12a and P12b reached a decision of the direction without tapping the screen at all (see Fig. 9): “What if we choose this area? [Turns the phone to point to direction they were walking and points some icons with his finger]” (P12b, Male 21 years, French). “[Leans over to look at the phone] Yeah it has some cafés, and green area” (P12a, Male 22 years, Chinese). “The green area will be here [points with his finger first at the thumbnail of an image and then to group of park icons on the screen]” (P12b). “OK, let's go” (P12a). Participants already familiar with some parts of the city center (P3, P4, P5a, P5b, P9 and P10a) chose venues they saw in the app and had not known to exist.

Fig. 9 Participant P12b pointing the park icons (the faces of the participants are blurred for the purpose of their anonymity)

P1, P2, P7, P8 and P12 employed a strategy where they chose a cluster with many venues and walked there (see Fig. 10). Only when arriving in the area, did they look more carefully (from Uncover) for the names and images of the nearby venues to recognize them in their surroundings. This is in line with what foraging theory states: the areas that provide several potentially valuable items close to each other should be prioritized.

Sometimes the area was atmospheric, and the actual venues proved to be less important than what a cluster of them revealed about the area: *"The area was nice. I was actually enjoying it more than the buildings themselves"* (P3, Male, 30 years, Canadian). This further supports the design goal of supporting finding areas, not just individual venues. Providing the venue clusters by not hiding any icons even if they overlapped each other's proved useful for participants, as they could identify interesting areas to visit, even beyond the actual venues depicted.

Fig. 10 Participant P7b suggests they should visit next the cluster left of the highlighted icon. P7a agrees: "Yeah, looks crowded" (the faces of the participants are blurred for the purpose of their anonymity)

Overlapping icons did cause frustration too, since tapping a particular one became a challenge, and really tight clusters blocked details of the map, like street names and bridges. This shows that there is room for optimizing the visualization, but highlighting, not hiding the clusters, provides value, and confirms the design choice made in the beginning.

The venues or clusters participants chose to visit were old buildings (50% of the cases), parks (28%) and cafés (22%). This is in line with our previous findings [5], as distinctive architecture and pleasurable views were prioritized. P1 and P7 noted that seeing the opening hours, or filtering based on them, would be important.

5.4.3. Navigation

After selecting a destination with the application, participants kept the destination icon selected while walking towards it to support the navigation. Updating the orientation of venue icons based on the compass gave some participants a feeling of having a landmark in the distance: *"In some cities, you have really high buildings or towers. [...] This compass gives you the same feeling like there is this imaginary high point [you can see all the time]."* (P3, Male, 30 years, Canadian)

When reaching a crossing, they either estimated directly from the position of the destination icon the best option to take, or they stopped to scan with the phone for a couple seconds to see how the icon settles when pointing towards

the available streets. Because of the dynamic nature of the exploration activity, participants valued the egocentric orientation of the radar/map in the application, which kept on supporting their navigation whichever route they chose to take. *"What works really good is the orientation. It shows you where you are going right now, it works well"* (P7b, Male, 23 years, German). Egocentric orientation provided the direction to walk to at a glance, but since the system did not highlight any intermediary landmarks visible on the way, the participants ended up checking the screen in most of the crossings, which kept some of the focus on the device during the walking. The drift of the orientation sensor values in Nexus 6 caused some confusion but, especially on the map view, it was easy to see when the streets on the map did not align with the real world anymore. In these cases, the researcher suggested that participants should move the phone in the figure eight pattern to re-calibrate the compass.

One of the main design objectives for the application was providing the information while only minimally interfering with experiencing the surroundings. As described in Section 5.4.2, in 82% of the cases the next destination was selected with 0 to 2 taps on the user interface and 69% of these in under 15 seconds. Still, in the final questionnaire the statement "the app distracted me from my environment" got more mixed answers than the rest of the questions with median 4, i.e. neutral, and interquartile range 2.5. One reason for this might be the navigation phase, where users still needed to orient with the position of the destination many times whilst walking there. Even if they referred to the feeling of having a virtual landmark in the distance, it required looking the phone and, in some cases, letting the compass settle, which required focusing the attention away from the environment. A bug where the selected venue might become unselected after a couple minutes further accentuated this, as it required finding the destination icon again. Other display methods providing peripheral, and persistent, cues of the location of the virtual landmark might help in this regard.

As can be seen in Fig. 6, the majority (66%) of participants used map mode at least 72% of the time, and a half of participants almost exclusively. For them, it was important to see the streets in the application, so they had more hints helping to orient the virtual information on the application with the real world around them.

The remaining 33% of participants used radar at least 69 % of the time. Some of them valued the simplicity of just keeping the destination icon in the front sector. In the map view the sectors were not explicitly drawn, so they felt navigation was more complex with that: *"The good thing is that you have this axis so I just need to walk to a general direction. So, that is easy for someone [like me] who is really bad at navigating. If you put a map, then I start to think I need to turn here to go there"* (P1, Male, 26 years, Singaporean). Answers to the questionnaire regarding planning and exploration orientation did not have visible effect on the preference between map and radar, as both travelling styles were represented equally in radar preferring participants.

The radar graphics was designed to support the decisions between forward, left and right directions that are most common in cities with a grid plan, while also reducing the clutter distracting from recognizing the icons and clusters. For two participants, it worked just like that, and for two others the limited information on the radar made the whole activity feel like a game: *"It's like chasse de trésor! [treasure hunt]"* (P10b, Male, 21 years, French). This suggests an opportunity to support the playful aspects of exploration more directly. Some virtual content might require unlocking it by visiting the area, for example. Further studies could play more with restricting some information and gamifying the exploration, like for example Ballagas et al. [34] and Pokémon GO game [45] have done.

Some obstacles, like wide buildings and railway tracks, were not visible in the radar view, so participants using the radar became aware of them only when they had walked close enough to see them in the real world. In case of a building, it was enough to switch from radar to map for a short while to decide which way one should go around it. In two cases, using the radar left the user unaware of the railway yard on the way, and they decided to abandon the planned destination when arriving and seeing the tracks in front of them. This underlines the obvious limitation of the radar view. Some of the information omitted from it is important for the navigation, so optimal simplification of the map should retain the largest obstacles, like rivers and railroads.

5.4.4. Information about Nearby Venues

Some of the application usage was clearly inspired by the things participants saw around them: *"That looks cool what is that?"* (P10a, Female, 20 years, Finnish). When walking towards the destination and passing an interesting looking building, such as a church or the presidential palace, participants took the application, pointed the phone towards the building, checked if the image would be visible, and if the application could provide them information about it. The automatic updating of images made the task very natural: *"It's magic, if you just turn this, it's there"* (P12b, Male, 21 years, French). Updating the images instantly by pointing fitted well with the exploration where attention is constantly redirected to new things. For this task, the relaxed precision of registering the images was adequate and none of the participants were asking for the images to be placed in their view of the real world, as would have been commonly done in AR.

In some cases, the images were clearly taken in the summer, and differed from what participants saw ahead of them in winter. On one hand, arriving at a park where trees have dropped all leaves was in some way a disappointment, on the other, images conveyed a bit of the charm the places have in the summer, which was valued: *“So green!”* (P12c, Female, 23 years, German). Providing images both from current and other seasons for each venue could be a useful addition to further support understanding the meaning of the places, similarly as discussed in one of our earlier studies [46].

5.4.5. Information about Distant Venues

Occasionally, participants became interested about venues that were too far to see in the environment, but were visible in Uncover. Seven participants, while walking to the destination they had decided, checked from the application a few venues that were near the route they were walking. Even though they had chosen a venue to visit next, the decision was open to reconsideration. If another venue seemed interesting in the application, they checked more information about it to see if it is worth a detour. Somewhat against our expectations the participants often chose quite distant venues to visit, which meant that walking and navigating there took some time. The average plan length from deciding a place to see to deciding a next one was 9.5 min. On one hand, this seems like a deviation from the exploration behavior as the participants did not change their plan more often. On the other hand, checking distant venues from the Uncover while walking to the previously decided destination reveals that they were open for making detours. Regardless of keeping with a plan for a few minutes at a time, all participants felt they were spontaneous: *“We don’t really have a plan, it’s just like we haven’t been there and there, and then we just pick it”* (P5b, Female, 26 years, Thai). Feeling spontaneous seems to have more to do with making quick decisions than changing them often. Additionally, this suggests that exploration happens on several levels. There is high-level exploration on the areas to visit and lower-level exploration on specific locations on the way, and when reaching the destination areas.

P6 was travelling part of the time in a tram and used the time to get an idea of the opportunities available in the areas she was passing: *“There are many good places to visit around that I didn’t know were so close”* (P6, Female, 35 years, Peruvian). The view from the tram was blocked by nearby buildings, so the app extended the participant’s vision and revealed venues that the participant had not previously noticed.

6. DISCUSSION

The design of Uncover was informed by optimal foraging theory to focus on supporting estimating the value different areas might provide and the effort required to reach them. The specific design objective for Uncover was supporting finding things tourists value, like pleasurable views and distinctive architecture, and doing it in a way that only minimally interferes with experiencing the surroundings and feels like exploration. Minimizing the interference and providing the value estimates was supported with several design choices: (1) providing egocentric views of POIs, (2) keeping the clusters visible, (3) providing venue images automatically from the direction the phone points to, as well as (4) providing a radar view for situations where the map is not needed and people prefer to focus on the venues.

6.1. Successfulness of the design choices

When reviewing the successfulness of the design choices, egocentric views worked especially well with nearby content when participants wanted to check what the building they could see was, providing contextual information about the environment. Getting the venue image to the image grid just by pointing the phone towards the venue was even commented to feel 'magical'. Egocentric map and radar views also provided a virtual landmark that could be used during navigation, making it enough to orient oneself so that the selected venue stays on top of the display while walking. On one hand this reduced the mental effort required to orient with the navigation instructions, but on the other hand, since the only landmark was the virtual one, it required directing one’s focus on the device regularly. The latter contributed to the mixed feedback about being distracted from the environment. The venues the participants chose to visit were more distant than what we anticipated while designing Uncover, so there was more navigation-related use in the field study than we expected. Therefore, future versions should pay more attention to the needs in the navigation phase to minimize the distraction from enjoying the environment.

Participants were able to find interesting locations with minimal taps. It suggests that, in terms of foraging theory, estimating the value was efficient. Several users chose to visit areas with clusters of venues to maximize the potential value they would get, as foraging theory [15] predicts. However, the radar view omitted some obstacles on the way to the chosen location, hampering the quality of the estimates of effort. In two cases, participants chose another location when the true effort of reaching their original destination proved to be higher than expected. This is also in line with what foraging theory would predict. Foraging theory proved to be a useful lens for studying the behavior

around exploring cities and our work shows that foraging theory can be used to guide the design of tools supporting exploration.

6.2. Comparison with commercial systems

The study method is identical to our earlier study where people were using only commercially available applications and non-digital tools, such as paper maps [5], so we can make some informal comparisons between the behavior in the two studies. However, one has to remain somewhat cautious as the people participating the studies are different and the time of the year (summer vs. winter) differs as well. For example, parks are scenic in the summer and invite exploration more than in the winter. With commercially available applications, choosing the places to visit required reading web pages of popular sights to visit and then finding them again from the map application to estimate the effort to reach it. Another alternative was to carry a paper map and choose the venues to visit from the ones that are prominently displayed on it, or purely rely on what one sees around in the immediate environment. Using Uncover mostly resembled exploration with paper maps, as the participants were able to easily see options that are beyond their immediate field-of-view and got some navigation support to reach them. Uncover provided more options to visit than what were highlighted on the paper maps, and a much faster way to orient with the navigation directions, as the egocentric orientation provided the correct direction to walk at all times. Compared to purely relying on what one sees, Uncover allowed participants to find venues that were beyond their field-of-view at the time of making the decision but also required directing some attention to it, which could become distracting if the venue was far away and required longer navigation. Choosing the venues to visit with Uncover by rotating the phone and tapping the images that caught the participants' attention was also much more effortless than reading web pages and locating the places again on the map application. All in all, Uncover improved the experience in several ways, especially compared to the existing digital tools. The improvements over physical tools were related to wider and dynamic selection of venues and straightforward navigation, but came with the expense of some time spent on looking at the display of the device.

After the study published in [5] Google Maps has introduced some features that are aimed to support exploration. A menu on the bottom of the screen allows seeing on the map the locations of venues belonging to certain categories. Images of each of these are also available by clicking the icons on the map but can be seen from a couple venues at a time. One has to explore these venue categories one by one, and the amount of venues highlighted is very limited, so the app does not provide overviews of areas in a way Uncover does. Google Maps also does not allow scanning images of nearby venues just by pointing the phone towards the direction one is interested. Getting a visual overview of the area would require clicking the different venue icons and switching the venue type when necessary. It is clearly focused on choosing one venue to visit, and not on getting overview of areas, as Uncover is.

6.3. Comparison with eyes-free navigation research

Several eyes-free navigation systems have been proposed to support exploration of cities e.g. [6–9]. They expect the user to be on a way to a specific destination and make it easier to pay attention to things on the way, which could lead to exploration, but such solutions do not support the actual exploration. They also do not report how people experienced the exploration, or if any of that happened in the evaluations. Conversely, Uncover field study participants were using it for city exploration by finding places to visit and getting info on things they were passing. They also used it for navigation to the places they found so, in Allen's [2] terms, it supported both travel with the goal of reaching a novel destination, and exploratory travel.

7. FUTURE WORK

The design of Uncover was optimized for deciding the venues to visit and checking information about them quickly. A future version should pay more attention to the navigation phase as well, and provide an optimized mode for keeping tabs on the direction one should be heading. Adding complementary modalities, like vibration, could alleviate the distraction this activity creates.

The combination of a lab study and a field study allowed concentrating on the short-term dynamics of exploration activity but a longer-term experience of using a digital tool to support the exploration and how other tools would be used along it would be an interesting future work topic. A longitudinal field study with self-reporting methods could be used for studying that. That will require installing Uncover on the participants' own phones, which will require some polishing so that it handles for example different Android versions properly. The data on the short-term dynamics described in this paper will support designing the self-report tools and will complement the results of that study to provide more complete picture of exploration experience.

8. CONCLUSIONS

This paper reports two studies, which examine the ways to support city exploration and finding things tourists value, like pleasurable views and distinctive architecture, while interfering with experiencing the surroundings as little as

possible. The studies confirmed the value of foraging theory in guiding the design to highlight clusters of content and support estimating the effort to reach them. A pilot study done in the lab tested the effect of different marker types and backgrounds on the time to recognize the direction with most content. Icons proved to work significantly faster than the alternatives, so they were implemented to the final prototype. A field study analyzed the city exploration behavior participants exhibited while using the prototype. The prototype allowed participants to explore their options rather than search for them. The study showed that supporting the exploration can be improved by enabling features that are either disabled by default or not available at all in commercial map applications, like egocentric orientation of the map, providing images of venues just by pointing to their direction, and displaying clusters of several venue types. All these suggested changes relate to keeping the virtual content automatically in sync with where the user is focusing, so being able to better support the exploratory navigation comes down to recognizing the dynamic nature of exploration and minimizing the effort required to get the support.

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