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ORIGINAL ARTICLE

This is not classified: everyday information seeking and encountering in smart urban spaces

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Abstract We present a multipronged comparative study of citizens' self-proclaimed information needs and actual information seeking behavior in smart urban spaces. We first conducted several user studies to identify the types of information services that citizens believed to be useful in urban setting utilizing methods ranging from contextual inquiry with lo-fi prototypes to "card sorting" exercise with a separate set of participants, and finally to implementing selected services. We then made a sizeable constructive intervention into the urban space by deploying in a city center 12 large, interactive public displays called "hotspots" to offer a wide range of previously identified information services. We collected comprehensive qualitative and quantitative data on the usage of the hotspots and their services by the general public during 13 months. Our study reveals discrepancies between a priori and a posteriori information seeking strategies extracted from the self-proclaimed information needs and the actual usage of the hotspots.

Keywords Urban computing · Large public displays · Ubiquitous computing · Information seeking · Information encountering

1 Introduction

The contemporary urban cityscape is becoming increasingly saturated with different types of pervasive computing technology. Mobile devices offering continuous access to Internet resources have become a basic commodity carried by almost everyone, offering new possibilities and ways of seeking information, and communicating with dislocated networks of friends, family, and colleagues. Large public screens provide a powerful visual element and are often used to broadcast information and, increasingly, to provide different types of interaction possibilities [16, 26]. Heterogeneous sensor systems regularly measure and analyze the environment, and provide a detailed view on their surroundings from air quality to traffic patterns and weather conditions [5].

A consequence of the proliferation of technology and digital information in the urban landscape is that the ways people seek information is changing. Traditional information and communication artifacts, such as public phone booths with phone directories, have rapidly disappeared, while printed information such as timetables in public transportation stops is slowly becoming obsolete in favor of digital boards providing enriched real-time information. Furthermore, interactive displays are gaining popularity due to their increased ability to visualize information and services, as well as their capacity for allowing users to browse for more detailed information or even take away that information on a personal mobile device for later reference [12, 16]. The adoption of emergent technologies in urban contexts suggests that urban environments are high-demand information spaces where people rely on many types of dynamic information cues found in the environment and, increasingly, in the digital counterpart of the physical world.

This study aims to elicit the information seeking strategies employed by people in urban spaces with two complementary and comparative approaches. First, we present several user studies to identify information services people believe to be useful in urban setting. Then, given the

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findings of the user studies, we introduce the concept of information "hotspot" to provide a wide range of such information services. We implemented the hotspot as an interactive public display embedded with other computing resources (Fig. 1) and deployed 12 such hotspots in indoor and outdoor locations around the downtown area of the city of Oulu, Finland, a medium-sized city of about 140,000. We collected comprehensive qualitative and quantitative data on the usage of the hotspots by thousands of members of the general public during 13 months, and compare the information seeking strategies extracted from the self-proclaimed information needs to those extracted from the actual usage of the hotspots. The analysis is grounded on theories on human information behavior (HIB), in particular those on information encountering and foraging.

2 Information seeking in urban spaces

For millennia, humans have sought, organized, and used information as they learned and evolved patterns of human information behavior to resolve problems of survival, work, and everyday life [7]. Information behavior has been defined as "the totality of human behavior in relation to sources and channels of information, including both active and passive information seeking, and ultimately, information use" [28]. In this sense, information seeking is defined as a subset of information behavior that includes the purposive seeking of information in relation to a goal [24], while information use is "the physical and mental acts humans employ to incorporate found information into their knowledge base or knowledge structure" [28].

Fig. 1 An outdoor hotspot

2.1 Approaches to information seeking

Historically, the information seeking approach has been dominant in library and information science research [28]. Other major approaches have emerged, however, including information seeking and problem solving (e.g., [4, 7]), everyday life information seeking [23], and information foraging [4, 21]. However, none of these approaches alone can completely explain human behavior related to finding information, and especially with the advent of the Internet new approaches have attempted to overcome the inherent limitations of the more traditional models [7, 24].

Information foraging theory has been used to examine human interaction with information retrieval and Web systems. The theory defines time costs, resource costs, and opportunity costs of different information foraging and sense-making strategies, including access, recognition, and handling costs, which are weighed against the rate at which useful information is delivered [24]. Thus, in analogy to a predator developing optimal foraging patterns for food from the environment, information sources will also have different profitability in terms of the amount of valuable information returned per unit cost in processing the source. Therefore, information sources that are easily accessible and have a high rate of return-per-cost will become more prevalent, or less effortful to access, than others.

Endemic to information foraging is the concept of information scent, which reflects the profitability of an information source in relation to other potential sources [21]. Given a strong scent, the information forager can quickly reach their information goal. In the absence of a strong scent, the forager can at best perform a "random walk" through the environment and find a new direction by sniffing for scent activities [24]. Scent-following activities involve the information forager using proximal cues found in the environment to ensure the optimal selection of "prey information" from a variety of possible alternatives. Scent following is the "perception of the value, cost, or access path of information sources obtained from proximal cues, such as bibliographic citations, WWW links, or icons representing the sources" [21].

More recently, social information foraging [20] has shown that a group of people can more efficiently discover, invent, and innovate than a single user. Undiscovered public knowledge can be found when groups forage for information and bridge between two network clusters of knowledge and information.

Such social aspects of information seeking are quite relevant to urban spaces where people come to meet and spend time with their friends and families. In this paper, information foraging and information scent are of most relevance in the context of in situ urban information needs, and specifically to public interactive displays. Since such displays are large and highly visible, people can get a strong information scent and follow it to the closest display, arguably reducing the "random walks" through the environment in the search of a new information scent.

2.2 Information needs and urban residents

Providing strong information scents is important in public spaces because the fulfillment of everyday needs depends on acquiring information: communication theorists posit information acquisition and its proper use as the basis of effective human functioning [1]. Further evidence shows that information use is strongly related to an individual's ability to make decisions, willingness to take risks, ability to achieve successful outcomes, and can even affect his/her feelings of personal effectiveness [29].

However, it has been pointed out that due to the increasing amounts of information available, people have trouble locating the relevant sources for the information in their everyday lives [2]. In one study, urban teenagers were found to view traditional sources of information (such as libraries) as "uncool" and uninviting [32], and relied solely on newer ways of finding relevant information. Ideally, these new types of information sources should be readily available in their context of use, thus enhancing their information scent and reducing the number of "random walks" necessary to locate information.

This very problem was already addressed in a detailed report of urban information needs of Baltimore residents as early as 1973 [29]. The report begins by addressing the core problem:

> Existing information technology, although rapidly developing, has not kept pace with the information explosion. One arena in which the technology and theory has especially lacked behind is that of the development and management of delivery systems for the information needs of the urban public.

Thus, urban spaces can be seen as a veritable smorgasbord of people with differing goals, activities, needs, and available resources, making any single service or selection of services unlikely to satisfy all of people's information needs. For instance, a study by Dervin [9] found that 185 respondents generated 160 information needs in response to a single survey questionnaire item.

2.3 Large displays in urban spaces

Large public displays have recently attracted attention from both public entities and research organizations due to their decreasing cost and increased visual output [26]. Such displays can be categorized as reference displays and interactive displays. Reference displays are designed for unidirectional broadcasting of digital information and signage. They require relatively small setup effort, but often suffer from short attention spans [13] and so-called display blindness [16].

Although some commercial interactive display installations such as the BBC Big Screens (http://www.bbc.co.uk/bigscreens) exist, most efforts in this category are carried out by research projects. The CityWall [22] installation in downtown Helsinki focused on analyzing the emerging social interaction patterns related to a public interaction setting. Besides identifying interaction roles such as mentoring and ad hoc collaboration, they also verified the so-called "honey pot" phenomenon identified also in [6, 14]. This concept suggests that an ongoing interaction on a public display serves as an attention incentive for others, thus serving as the most effective way for public to learn about the display's interactive affordances and allow subtle shifting between being an onlooker and a participant. This behavior can also be linked to social information foraging, whereby users are possibly inclined to imitate others in their information seeking behavior.

The iDisplays project [16] conducted an evaluation where public displays were utilized to provide context-aware guidance information to users based on their pre-planned route information. Findings indicate that public displays were useful in the early phase of route planning due to the visual capacity. During the navigation, however, users resorted to public displays only when temporarily straying from the planned route. This can be seen as a temporary need for information foraging, after which users continued the route.

The eCampus project [25] features a network of large public displays on the Lancaster university campus. Experiments on this display network include the utilization of constraint-based schedulers for content used in broadcasting in different use-cases. These experiments highlight the location-aware presentation of the content, thus adhering to the calm esthetics principle highlighted in [27].

A thorough review of past research on interactive public displays is provided by Müller et al. [17]. Our study differs from other studies in terms of scale, setting, time span, and service offering. While most other studies have deployed a single display for a relatively short time in an artificial lab or campus setting, we have deployed a network of 12 hotspots in authentic urban setting for over a year. Further, while in most other studies an interactive public display is typically designed to provide one particular service, our hotspots provide a wide range of services, which allows us to explore the information seeking strategies of real users.

2.4 Designing public hotspots of information

The longitudinal deployment of hotspots described here can be considered as a *constructive intervention* where visible, tangible constructs are placed in a public setting and left "in the wild" for people to use. Constructive interventions can be seen as similar to *urban probes* [19], but with more "heavyweight" and mature constructs that can survive a long-term deployment in the wild.

Information behavior theories can provide grounding in designing the service offering of such interactive public displays. Typically, they are deployed for large masses of people in high information-demand spaces, for example at airports and city centers. Thus, it can be argued that they are deployed to support in situ information needs, to provide information shortcuts and, crucially, to support everyday information encountering [10] and information foraging [21].

Here, in situ information needs refer to information needs that arise suddenly based on a person's current context. Thus, questions such as "when does the next bus leave", or "where is the nearest open restaurant" can be seen as in situ needs, as they arise in the moment and are related to a certain (urban) context. Such needs relate to Bates' "berrypicking" model [3], with the exception that berrypicking describes information seeking in the context of a particular evolving problem/solution process, whereas our concept encompasses a matrix of information needs within a certain context.

Public displays are also ideal for providing information shortcuts, which reduce the perceived distance from an information need to a solution. Our hotspots have been designed to serve as such shortcuts, in that accessing useful contextual information through them only requires a few clicks, thus making them a highly profitable source of information as stipulated by the efficiency concept of information foraging theory.

As highly visible artifacts in urban space, the hotspots also support serendipitous everyday information encountering, where people may accidentally find useful information from the hotspots, even though not actively seeking for it. Such everyday information encountering refers to the process where people encounter digital information as they go about their daily routine, similarly to paper fliers and signage. This type of encounter typically requires less intention or focus from users than online information seeking or surfing with personal computers, mobile devices, or public kiosks [8]. In addition, it has been shown that such experiences can lead to further successful experiences, thus initiating a positive experience cycle [10].

3 Study objectives

The reviewed literature suggests that interactive public displays can be an effective mechanism for providing information sources with strong information scent. In addition, they are ideal for delivering contextual information and allow everyday information encountering. It is not clear, however, whether people's past experience and expectations regarding information scent affects their value judgments regarding which type of information services they believe are most valuable in a specific context. In other words, are the information needs identified a priori actually valuable to users in an urban context? This has important implications in designing information systems for public spaces: should the available information depend on users' self-proclaimed needs, or on their actual behavior?

In this two-part study, we first identify the users' self-proclaimed (a priori) information needs via a contextual inquiry with a low-fidelity mock-up of an interactive public display, questionnaires, interviews and a card sorting exercise. In the second part, we design the concept of a "hotspot" to provide most of the services identified in the user studies, deploy a network of 12 such hotspots in a city center and collect comprehensive data on the usage of the hotspots during 13 months. Finally, we compare the a priori and a posteriori information seeking strategies extracted from the data collected in the two parts.

The main contribution of the study is to:

- Determine the types of information that people perceive as valuable in an urban context,
- Compare self-proclaimed information needs to actual information seeking patterns in using a real-world system, and
- Establish whether constructive interventions into public urban space yield new insight into human information behavior.

4 Identification of information needs

Potential information needs were elicited through a user study in downtown area of Oulu. The objective was to identify the types of information people perceive as useful in a public urban setting, to collect feedback on the idea of large public displays in the cityscape, and to identify locations that people found appropriate for these kinds of displays.

The user study included observation, interviews, and a mock-up study with low-fidelity device manufactured to convey the idea of a large public display. Over a course of

2 days, researchers conducted 74 open-ended interviews with the display mock-up, effectively a whiteboard rigged on a stand with wheels, acting as a demonstration device (Fig. 2). The interviews were conducted in four central locations planned as potential display locations, and subsequently selected based on feedback received from people (locations 1, 2, 6, and 7 in Fig. 4). The final deployment of the actual displays, as highly visible and permanent additions to the cityscape, was naturally subject to formal approval by the city administration. While we initially surveyed over 30 candidate locations, the city officials instructed us to limit our deployment to the walking streets and the market place (∼selected outdoor locations) as there was "political will in the city council to invest in those areas". The locations also received positive response in the interviews.

Demographic data of the interviewees is shown in Table 1 (column "Interviews with mock-up"). Participants were asked to describe their information needs while attending their business in the downtown area, and were offered the possibility to interact with the mock-up by drawing their service ideas directly on the whiteboard. Nearly all interviews were videotaped for further analysis, and researchers also gathered an extensive set of field notes and photographs.

Overall, the feedback received from people was positive and encouraging. People reacted positively to the idea of public displays in urban space, and proceeded to suggest several types of services as useful to their daily lives. Three researchers categorized the service suggestions independently, and the consolidated results identified 13 candidate services listed in Table 2.

Table 1 Demographic information of participants in user studies

	Study		
	Interviews with mock-up	Card sorting	Questionnaire
N	74	55	100
Gender distribution (%)			
Male	54	64	48
Female	32	36	46
N/A[a]	12	0	6
Age distribution (%)			
<15	0	0	12
15–24	35	11	31
25–34	14	65	16
35–50	14	20	15
51–65	17	4	21
>65	0	0	5
N/A[a]	20	0	0

[a] Gender and/or age were not recorded for all subjects

We subsequently conducted a card sorting exercise, where a different set of participants ($n = 55$) were instructed to individually rank all 13 candidate services in order of preference. Participants were told that the services represented candidates for deployment in the hotspots, and were asked to rate the service categories from the most useful to the least useful to them personally. The ratings of each participant were converted to points, giving the top service 13 points, the second service 12 points, all the way to the last (13th) service receiving one point. The average points for each service are shown in Table 2 under "Card

Fig. 2 Researchers conducting interviews with a mock-up display

Table 2 The services developed for this study

Service	Details	Card sorting		Actual hotspot usage	
		Avg.	Score (%)	Avg.	Score (%)
Maps	Where places are and what's near me	10.7	100	122	86
Transport	Public transportation schedules, location of transports etc.	10.7	100	6	4
Events	What's happening today/tomorrow/next week	9.3	87	15	10
Food	Restaurant menus, happy hours etc.	8.8	82	9	6
Info	General information related to opening hours, local history, healthcare etc.	7.2	67	n/a	n/a
Weather	Weather information	7.2	67	n/a	n/a
Traffic	Free parking spaces, construction sites, traffic jams etc.	6.8	64	n/a	n/a
Ads	Offers from stores, where to buy etc.	6.7	63	6	4
News	News from national and international sources	6.6	62	142	100
Media	Images, video, live streaming etc.	4.7	44	82	57
Uploads	Possibility to contribute own content	4	37	45	32
Municipal	Information about municipal decisions, council meetings etc.	3.7	35	5	3
Fun	Games, quizzes, and fun	3.3	31	139	98
Survey	Questionnaires regarding the hotspots	n/a	n/a	100	70

sorting", along with a normalized score for each service. The analysis showed that the between-service variation of scores is significant ($F(1,697) = 39.648$, $p < 0.0001$).

Overall 38% of respondents (11 male, 10 female) indicated *map* as the most important service category, while 20% (9 male, 2 female) ranked *public transportation* services as number 1. Further analysis revealed certain gender-based and age-based differences in preferences.

Females rated *commercial services* higher than males with an average of 8.15 points versus 5.8 from male ($F(1,52) = 4.4752, p < 0.05$). Females also rated higher *weather services* (average 8.5 vs. 6.5, $F(1,52) = 1.706, p < 0.05$). Males rated *multimedia services* higher (average 5.1 vs. 3.9, $F(1,52) = 5.6291, p < 0.05$), as well as *upload-driven services* (average 4.7 vs. 2.8, $F(1,52) = 6.5623, p < 0.05$).

Older respondents rated *map services* higher than younger ones with approximately a 5-point difference between the oldest and youngest age groups ($F(3,52) = 3.4292$, $p < 0.05$). Younger respondents rated higher the *food service* with approximately 3-point difference between the youngest and oldest age groups ($F(3,52) = 3.8338$, $p < 0.05$).

To capture latent trends in participants' preferences an eigenvector analysis was conducted on the service preference scores. Eigenvector analysis allows for identifying the few dimensions (eigenvectors) in the data that explain most of the data's variance. Each variable obtains a "loading" describing the extent to which it correlates with the identified dimensions. In this case, the first two dimensions identified explain more than 50% of the variance in the data. The loading for each service is plotted against the first two eigenvectors as shown in Fig. 3.

5 Actual usage of the hotspots

After consolidating the results of the first part of the study, prototype implementations of most of the services were designed and iterated from low-tech prototypes to full-fledged applications deployed in the city center for 24/7 access by the general public. Some services identified in the user study were not implemented due to various constraints, for example if content required by a particular service was not available. While a detailed technical description of the hotspots and their services is beyond the scope of this paper (see [18]), we provide here a brief overview.

In total, 12 hotspots were deployed across the city center (Fig. 4), six outdoors along the main walking streets of the City and at the market place, and six indoors in popular public buildings including the city library, a swimming hall, and the youth and culture center. Each hotspot consists of a high-definition 57″ touch screen enabled LCD panel, a high-end control PC, two integrated cameras enabling interaction through face detection algorithms, an RFID-reader, and access points for WiFi and Bluetooth networks. The access points create a wireless "hotspot" around the device, thus motivating the general name hotspot instead of display for our construct. The indoor hotspots are single-sided and moveable as they come with a wheeled base. The outdoor hotspots are two-sided with both sides having their own control PCs and they are installed solidly into the street.

The interaction model of the hotspots is based on Vogel's framework of four separate interaction phases [27]: *ambient display phase*, *implicit interaction phase*,

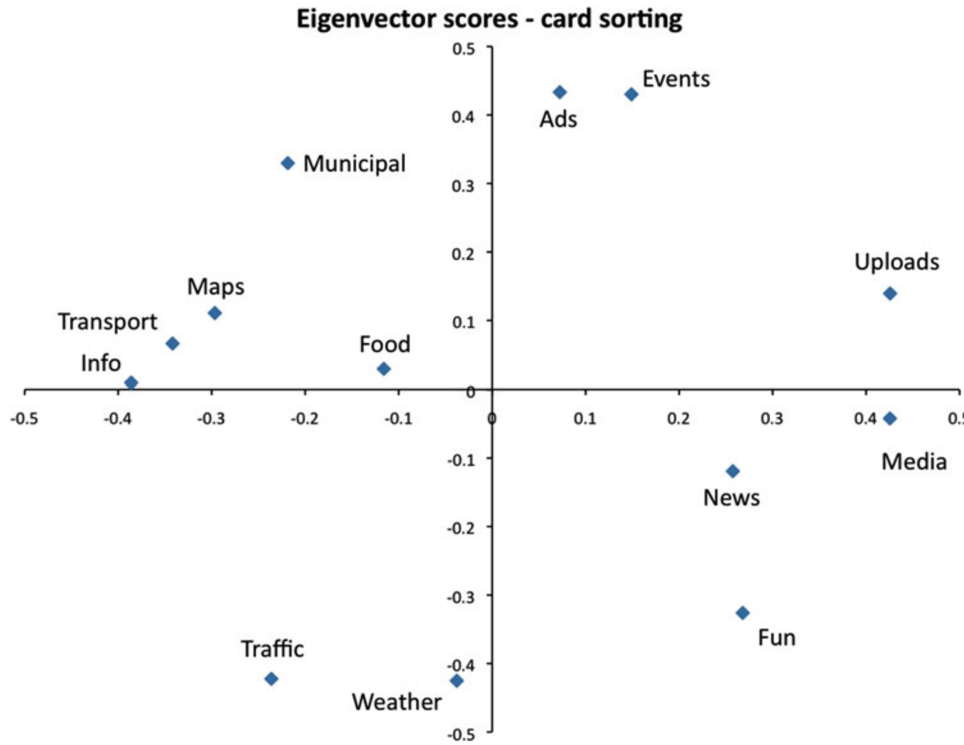

Fig. 3 Eigenvector scatterplot of service usefulness based on participant's subjective assessment

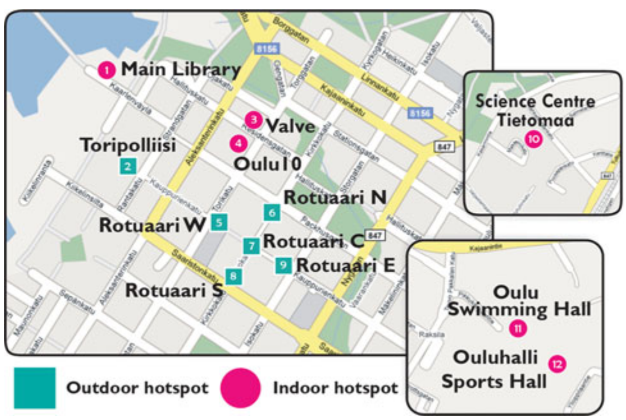

Fig. 4 Locations of the 12 hotspots

subtle interaction phase, and *personal interaction phase*. In our design, *implicit interaction* is omitted, as it is difficult to determine whether a single person is available to communication in a crowded public space.

The hotspots' state-machine defaults to idle (i.e., no interaction), and the hotspot is in *broadcast mode* (Vogel's ambient display phase), utilizing the full visual capacity of the display to broadcast both commercial and noncommercial content. When a person approaches the hotspot, the integrated cameras running face detection software trigger a transition to *subtle interaction mode*, and start showing an animation enticing the potential user(s) to start interacting with the screen. After a user touches the screen, the hotspot goes into *interactive mode* (Vogel's personal interaction phase) where the broadcast channel is "squeezed" into the upper left quadrant of the screen, and the rest of the screen space is dedicated to interactive applications (Fig. 5).

The services deployed on the hotspots were designed to reflect the concept of *information shortcuts* in urban space. As shown in Fig. 5, the bottom of the screen houses the "menu bar" with options for languages, a login button, visual theme selection button, a start-button, thumbs-up and thumbs-down voting buttons, event calendar, and clock. The start-button pops up a menu with all available services.

As with many real-world systems, there were occasional technical problems with the system, as well as an incremental update of the available services, which did not affect their core functionality.

5.1 Quantitative data

Quantitative data was gathered by logging all interaction events in the hotspots during 13 months from July 2009 till August 2010. While the log does not contain user identifiable information, it shows which services were launched within each session. A new session is registered from the moment a hotspot enters interactive mode until it reverts back to broadcast mode after a period of inactivity. A session was expected to be conducted by a single user or a small set of users.

During the 13 month period, 259,340 service launches were recorded. A service launch corresponds to a user

Fig. 5 Hotspot user interface in interactive mode

explicitly touching one of the service icons in the hotspot menu. On average, most services where launched between 1 pm and 5 pm. An eigenvector analysis was conducted on the services launched within each individual session. One record was constructed per session containing dummy variables for each of the services launched during that session. This coding approximates preferences and strategies of individual users. The service loadings are plotted against the first two eigenvectors in Fig. 6. In this case, the first two eigenvectors explain more than 60% of the data's variance. The procedure for constructing this plot is identical to the one used for Fig. 4.

Table 2 shows the average number of daily launches of each service (under "actual hotspot usage"). In addition, a normalized score is calculated for each service (under "score"). The analysis showed that the between-service variation of daily launches is significant ($F(1,5158) = 319.03$, $p < 0.0001$). The Pearson correlation between the service normalized scores from card sorting and observation in Table 1 is -0.195, while a scatterplot of these normalized scores is shown in Fig. 7.

5.2 Qualitative data

Qualitative data was also collected in summers 2009 and 2010 with different methods. A team of researchers demonstrated in situ the use of the hotspots and services, and also conducted interviews and distributed questionnaires. Ethnographic fieldwork was conducted to understand users' interaction and experience with the hotspots and their services. This included passive observation of users (10 h) and participatory observations (12 h) during public events where researchers help and guide passers-by in using the hotspots. In addition, a short questionnaire was distributed in situ, containing statements on a 5-point Likert scale (1 = disagree … 5 = agree). Additionally, users could answer the same questionnaire directly on the hotspots. The questionnaire contained more questions than presented here, as we wanted to gather data for several studies at once. The questions relevant to this particular study are discussed here.

The combined results and number of respondents per question are shown in Table 3. In the table, answers 5 and 4 are considered as *agree*, 3 as *neutral* or *no opinion*, and 1 and 2 as *disagree*. The demographic information of the respondents is shown in Table 1 (column "questionnaire").

6 Discussion

The discussion focuses on developing an understanding of how users seek information, the strategies they develop, and the services they perceive as useful.

6.1 Identification of information needs

Methodologically, the in situ mock-up display used during the initial ethnographic studies proved a valuable tool. As an artifact it attracted attention to the researchers and made it easier to elicit information from passers-by. In addition, the casual and familiar nature of the whiteboard made passers-by comfortable in sketching their ideas using life-sized drawing, thus grounding the reflection upon the discussed ideas and services. The vast majority of participants was quite positive about the idea of the hotspots, and most suggested that these could be quite valuable in their day-to-day activities. This was confirmed after the hotspots had been deployed, with most respondents claiming that the hotspots are a good fit for the city and they feel natural to use in a public setting (Table 3). A criticism about the

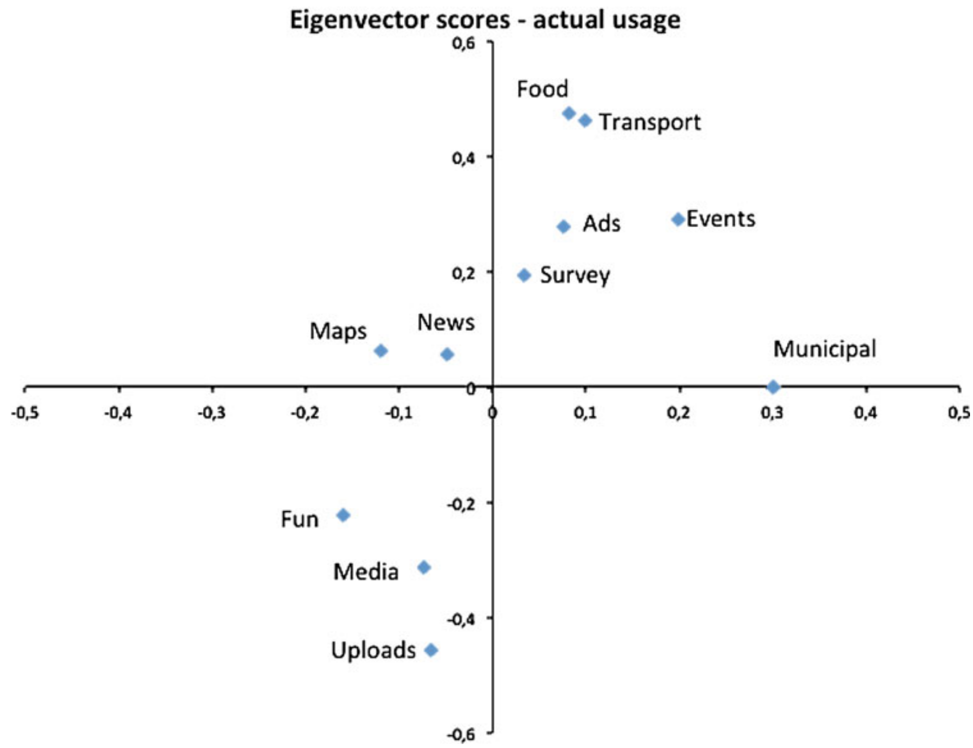

Fig. 6 Eigenvector scatterplot of service usefulness determined from actual usage

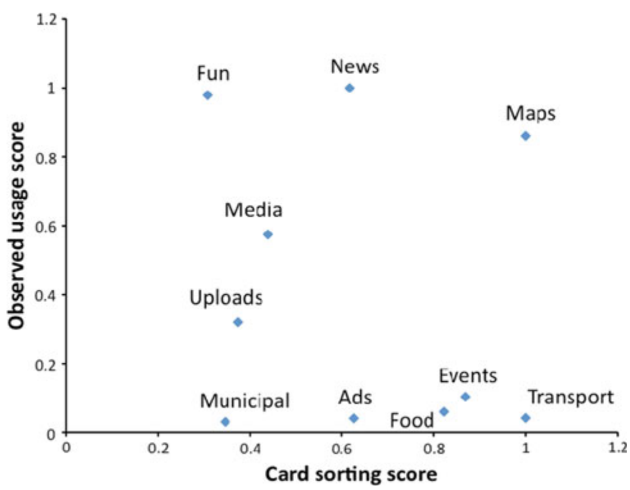

Fig. 7 Correlation between self-proclaimed (*x*-axis) and actual (*y*-axis) usefulness of services

deployed hotspots was the lack of usage instructions, while the public seemed split regarding the actual usefulness of the hotspots.

Interestingly, the initial user study highlighted a number of gender and age differences in terms of preference. Females rated higher commercial services, which included things such as offers from shops and suggestions on where to buy items. Females' stronger preference for weather services and males' interest in the public transportation services can't be explained without further qualitative user studies. However, earlier studies suggest that women are more interested in the contextual and practical side of technology, and men in the technology as such [31]. Males' stronger preference for multimedia and upload-driven services may also be due to the western cultural norms and values that label more complex technological tasks as the masculine domain [30]. Specifically, the upload-driven

Table 3 Respondents' assessment of selected statements regarding the hotspots

Statement	N[a]	Agree (%)	Neutral (%)	Disagree (%)
UBI-hotspots fit in downtown city	197	76	13	11
Using hotspots feels natural in a public setting	182	74	15	12
The UI is easy to understand	262	63	16	21
Hotspots give enough instructions during use	317	46	13	41
I prefer using hotspots together with someone	185	59	19	22
I got useful information from the hotspots	216	44	19	37

[a] On-screen questionnaire contained 8 randomly selected questions from the in situ questionnaire, thus *N* varies

services would require users to pair their personal devices with the display, and this might be perceived as a technically challenging gadget-related task stereotypically akin to male preferences.

The age-related differences revealed, rather unsurprisingly, a strong preference of younger age groups for food services. The description of these services entailed the ability to find after-hour fast-food establishments, which are quite likely to appeal to younger respondents, like students. Conversely, older respondents had a strong preference for map services, possibly revealing a stronger interest in exploring the nearby environment and finding out about possibly new establishments.

6.2 Observations of actual usage and attitudes

During the deployment of the hotspots, a significant amount of ethnographic fieldwork was conducted to gain insights into the actual usage of the hotspots. Interestingly, most people taking part in the public training events where researchers demonstrated the use of the hotspots in public were adults and elderly: 22% were under 25 years; 33% 25–50 years; and 45% over 50 years. Typically, when bypassing teenagers were asked to participate they declined, claiming to already be familiar with the hotspots. It is likely that children and teenagers more readily test and adopt new technologies, and are more used to locating information from digital sources such as the Internet and, thus, are more prepared to search and find new information scents from an augmented environment [32]. Adults, on the other hand, rely on more traditional information sources. Thus, guidance was more necessary and popular among adults.

During the observations, attention was paid to the time and weather, approximate age and gender of the person and whether he or she was in company or alone. In particular, we took notice on how the person approached the hotspot and how s/he interacted with it, and with others. Most observations were conducted in the afternoon at location 2 (Fig. 4). This hotspot is located at a busy market area, which is a popular spot during the summer months due to a high concentration of restaurants and outdoor terraces, and is also popular among tourists. In addition, observations were conducted at the hotspots in the main library, the swimming Hall, and two further locations along the main walking/shopping streets of the City (locations 6 and 9 in Fig. 4). The total amount of observed sessions is 54.

The observations revealed that people approach the displays equally alone and in company. This is also confirmed by the questionnaire results (Table 3) where the majority of users prefer interacting with the hotspots when in a small group. This would suggest that using the hotspots to find information is considered a social activity, as proposed by social information foraging theory. During observations, people mostly just drifted near the display because it caught their attention; hence accidental *everyday information encountering* was common. However, in about a quarter of the sessions people gave the impression of determination while moving toward the display. They seemed to seek specific information, and while using the hotspots adults were, for example, checking the bus schedules or reading news. This would suggest that these users were already familiar with the technology, and had previously decided that the hotspots are a profitable information source as defined by information foraging theory. Thus, instead of seeking for optional information sources from the environment, they follow the information scent to the nearest hotspot and forage it for information.

Children, especially under the age of 12, preferred playing games and using other entertainment-related services in small groups. Children appeared to be familiar with the technology and applications.

The observations also indicate that people often pay attention to the hotspots from a distance when the display is in broadcast mode. In 63% of the observed sessions, someone actually touched the display, thus engaging in interactive mode. Usually this happened after a moment of hesitation, and due to the lightness of the touch or technical problems the interaction was not always successful. Once someone was interacting with the display, passers-by became interested and approached the display, thus clearly demonstrating the *honey pot* phenomenon in action. Participatory observation during the public training events confirms this remark. Typically, when there were a lot of people taking part and interacting with the display, many onlookers also became interested and engaged. This suggests that interactive public displays elicit social behavior, and serve as impromptu hubs for communication with co-located strangers.

6.3 Quantifying the actual usage of services

Orthogonal to the ethnographic observations, we have a rich log of all interaction events at each hotspot over a period of 13 months. The log reveals that the usage of all services followed a similar pattern, gradually increasing after mid-morning, reaching a peak at about 3 pm and eventually decreasing by 6 pm. This pattern was followed by all services, suggesting that the time of day did not significantly affect users' information seeking behavior. Friday and Saturday nights were much busier times due to the active nightlife of the city. The use of different displays varied across locations, which in not surprising since indoor displays are not accessible during the night, and similarly central downtown locations are rather busy during the weekends.

6.4 Self-proclaimed versus actual usefulness of services

Comparing the self-proclaimed usefulness of services against their actual usage yields interesting insights. The self-proclaimed usefulness data was collected in the user study conducted prior to the design and deployment of the hotspots and the services. The actual usefulness of the services is calculated based on how many times each service was used on a daily basis. Normalized scores for each service are presented in Table 2, while Fig. 7 shows the (rather low) correlation between the scores. It should be noted that Fig. 7 only contains the services that were actually implemented into the hotspots.

By focusing on Fig. 7, it is possible to identify the services that were underestimated or overestimated in their usefulness prior to their deployment. Specifically, the diagonal running from the bottom left to the top right is the axis along which services appear to be used as much as users expected to use them. Services below this diagonal are services whose usefulness was *overestimated*: these are services that were rated rather high on people's explicit preferences during card sorting, but were actually not used frequently on a daily basis. On the other hand, services above the diagonal were *underestimated*: these are services that were explicitly rated rather low compared to their actual frequency of use on a daily basis.

Most services were overestimated in their usefulness, and in fact there is a negative (albeit weak) correlation between self-proclaimed and actual usefulness of services. To further explore the differences between self-proclaimed information needs and actual information behavior, we analytically identify users' latent information seeking strategies as shown next.

6.5 Identification of self-proclaimed and actual information seeking strategies

The card sorting data gives further insight into users' various a priori strategies for information seeking. Figure 3 contains clusters of variables suggesting latent strategies for satisfying the respondents' self-proclaimed information needs. One cluster closely ties Traffic and Weather services, which is indicative of peoples' perceived need for making trips without weather disruption. This latent self-proclaimed behavior may be labeled as the *transport strategy*. A further cluster consists of the Info, Maps, and Public Transportation services, suggesting a strategy for exploring nearby places and destinations. This latent self-proclaimed behavior can be labeled as the *exploring strategy*. A third cluster consists of the Events and Ads, suggesting an interest in nearby commercial events. This latent self-proclaimed behavior can be labeled as the *consumer strategy*. Finally, a fourth cluster ties Fun, News, Media, and Uploaded Content, suggesting an interest in entertainment and news. This cluster can be labeled as the *outreach strategy*.

The a posteriori information seeking behavior can be extracted from the eigenvector analysis of the actual usage of the services (Fig. 6). Again four clusters can be identified. One cluster contains the Fun, Media, and Uploads services, suggesting that users use these three services in combination. This behavior can be labeled as the *entertainment* strategy. A second cluster consist of the Maps and News services, suggesting that people appear to be exploring the environment around them as well as catching up with recent events. This behavior can be labeled as the *encountering* strategy. A third cluster consists of the Survey, Ads, and Events services, and can be mapped to the previously identified *consumer* strategy. Finally, Food and Transport services are closely linked, suggesting users who are trying to locate a suitable establishment for eating as well as planning their route back home (possibly late at night). This behavior can be labeled as the *planning* strategy.

6.6 Understanding users' information seeking strategies

The analysis suggests some discrepancy between users' a priori strategies about information seeking in urban spaces and their explicit behavior. Specifically, one such a priori strategy is the *outreach* strategy, which consists of news and entertainment services. The observational data shows a segmentation of that strategy into the *entertainment* and *encountering* strategies. One interpretation for this segmentation is that while users' prior expectation was to use information portals for both news and entertainment, their actual behavior suggests that they either prefer to engage with the hotspots for fun and games, or to opportunistically "encounter" the hotspots for a quick update on news and nearby happenings.

Also, the Public Transportation services were a priori identified as part of the *exploring* strategy, whereby users appeared to associate this service with the map and general information services. However, in users' explicit behavior a *planning* strategy is much more prominent whereby finding a place to eat and planning the journey home are strongly associated. This discrepancy can be interpreted as an a priori expectation to be out and about exploring the city, when in fact users are most likely dealing with maintaining a schedule for getting back home, possibly late at night.

On the other hand, the a priori *consumer* strategy was actually observed during actual use of the system. It is interesting to note, however, that this strategy consists of services that were overestimated in their usefulness. Therefore, while this is a strategy that users' were accurate about expecting to adopt, they overestimated its usefulness.

Relating the a priori strategies to Fig. 7 suggests that in terms of information seeking behavior, participants' prior experience and expectations seem to overestimate consumer and exploring needs at the expense of information and outreach needs. Conversely, users' observable strategies were partly underestimated (entertainment and encountering) and partly overestimated (consumer and planning). This implies that while users did not expect to have fun with the hotspots, they actually do like to play games on them. Similarly, while users did not expect to read the news and be updated by these hotspots they actually are. However, this seems to happen in a rather opportunistic fashion judging by the observed strategies.

6.7 Usefulness of constructive interventions

As a research tool, we consider our hotspots to be a constructive intervention, akin to a heavyweight urban probes [19]. While expensive to install and maintain, they offer excellent opportunities for gaining insight into human information behavior with high external validity, as the hotspots have been used by thousands of real users on a daily basis for over a year in authentic urban setting. However, the purpose of constructive interventions differs from that of an urban probe in a crucial way: by deploying a heavyweight system longitudinally, users are able to overcome their preconceptions and assumptions about the system and can adapt their information behavior strategies. This differs from the purpose of urban probes, which are usually deployed over a short period of time and typically aim to understand and elicit users' initial reactions and thoughts. The study presented here highlights important ways in which users' expectations and preconceptions about their urban information needs do not fully match their observed behavior. It must, however, be kept in mind that the logging data cannot be used to identify users, and interpretations on the ways users from e.g., different age groups actually use the hotspots cannot be compared to the a priori user studies. More precise comparison requires vaster ethnographic fieldwork including both observations and interviews, which we will begin to conduct during the upcoming months. By deploying a number of hotspots for a sufficiently long time, we can establish the technical and cultural readiness and the critical mass of users needed for determining whether our hotspots can be deemed "(un)successful" [11].

6.8 Hotspots as information shortcuts

The user interface of the hotspots has been designed to support easy adoption, i.e., minimal technical expertise and training is required to access and use the services. Typically information is just three clicks away: first click to interactive mode, second to open the menu, third to access a service. This is in sharp contrast to findings from previous studies suggesting that people need on average 147 clicks to access the first three news items on a newspaper website using a modern mobile phone browser [15]. The same study showed that people needed, on average, 149 clicks on a mobile browser to access the bus schedules of a local public transportation company. As these are information items people access on the move, it is clear that the hotspots reduce the temporal distance to reaching an information goal. Further, due to the placement of the hotspots in downtown area, spatial distance to information is likely reduced when compared to other possible information sources. Therefore, the hotspots serve as information shortcuts in urban space, making information more accessible.

7 Conclusion

Public urban spaces augmented with pervasive computing infrastructure and services provide rich environments for research. Although research in such settings is expensive and time-consuming, data gathered from the use of services deployed in the wild provides new insight into how people from all walks of life react to and adopt these services as parts of their daily lives.

Human information behavior theories, although often used as tools in designing web-based information systems, have been overlooked when building pervasive computing services for urban spaces. This study has shown that these theories can be a basis for designing such services. Further, this study has identified a set of a priori and a posteriori information seeking strategies via a *constructive intervention* into public urban space. These strategies may be applied by other researchers as tools when designing new information services for smart urban spaces.

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