Lost in Navigation: Evaluating a Mobile Map App for a Fair

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ABSTRACT
This paper describes a field study evaluating a mobile map application for the Paris Air Show. The aim of the study was to investigate how well users can navigate (to static and moving targets) and orient themselves in a fair (an unknown environment posing realistic challenges for wayfinding) with a mobile map system. The study involved 14 fair visitors who carried out three navigation tasks, which required them to switch between map navigation and deciding upon their orientation in the physical environment. Our results indicate that navigation and orientation are not as tightly coupled as described in the traditional wayfinding literature and may require different modality approaches to optimally support users. Based on this, we draw design implications on how to balance supporting the user in navigation and orientation with mobile systems without diminishing users' awareness of their surroundings.

Categories and Subject Descriptors
H5.2. Information interfaces and presentation (e.g., HCI): Ergonomics; D.m. Miscellaneous: Software psychology.

Keywords
Mobile maps, pedestrian wayfinding, navigational aids, location-based services, friend finding, indoor localization.

1. INTRODUCTION
Wayfinding in large indoor environments is known to be difficult for various reasons, including low visibility of destinations beyond the direct surroundings [17], a lack of clear landmarks to aid navigation [1], loss of orientation when moving from one buiding or floor to another [6], and stimuli in the environment drawing attention [20]. Besides architectural features, various types of aids have traditionally been used to support people in navigating buildings, such as signs, route directions, and maps [1]. Research on wall-mounted and standing maps lists several features as important for a map's usefulness, including visible landmarks, a You-Are-Here symbol indicating the user's position, and alignment of the map with the user's orientation [8,16].

Map use triggers interaction in multiple modalities. For example, a study on the use of standing maps at a large fair showed that people often point and talk while interacting with the map, in order to make sense of the map, discuss and select potential destinations, and plan routes [2]. In order to support wayfinding, it is also important to realize that this is a multi-dimensional process, with multiple goals, which may conflict with each other. For example, improving wayfinding performance may be at the expense of the acquisition of an accurate cognitive map [3]. In many cases however, visitors of complex indoor environments, such as a fair, hospital, or airport, are not interested in acquiring an accurate cognitive map as much as getting to specific destinations without trouble. In this paper, we focus on the difference between *orientation*, which we define as the process of understanding one's own location and the direction of nearby destinations in relation to one's current location, and *navigation*, which we define as the process of moving to a destination.

In this paper, we present the results of a field study with a mobile map app developed specifically for a large international fair. A fair provides a suitable test-bed to investigate the relationship between navigation aids, navigation and orientation, as it poses real wayfinding challenges to visitors, due to unfamiliarity with the fair layout, the number of exhibits, and crowdedness.

The research questions addressed in this study are the following: To what extent does the mobile map app (which is state-of-the-art in publicly available mobile map apps) support orientation and navigation at the fair? What kinds of problems occur while using the app, in terms of wayfinding and usability?

The rest of the paper is structured as follows: first we provide a review of related work, followed by our study design and methods. We then describe and evaluate our results and conclude with design guidelines for mobile map-based navigation applications based on the self-localization paradigm as used in large, complex indoor environments.

2. RELATED WORK
2.1 Maps and Orientation
Orientation in the sense of understanding one's location in relation to the environment has traditionally been considered essential for wayfinding [7, 8]. When using a map, one needs to compare features (cues) of the surroundings with features (other cues) of the map [22]. To accurately determine one's own location, a single matching cue is not enough. Since direction is also a factor, at least two corresponding points have to be established to complete spatial localization [8]. Here, the map needs to be aligned (mentally or physically) with one's physical orientation in space, which is not straightforward [18]. For example, in maps for outdoor environments there is a strong convention of displaying North as up, but maps for indoor environments may follow different conventions, such as aligning the map with the main building axis. Car navigation systems often follow the convention of displaying the car's orientation as up, and this option has been implemented in systems for pedestrian navigation too (e.g., see [18], and Google Maps Navigation [5]).

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2.2 Indoor Navigation Systems

Research on mobile indoor navigation has so far focused on problems related to spatial orientation, resulting in work on cognitively adequate presentation of maps [14], facilitating localization and navigation via visual or audible landmarks [11], personalized navigation support [24], or supporting collaborative interaction [2, 4]. The underlying assumption of these works has been that localization, i.e. the system knows about and displays the position of the user and target destinations, supports orientation, and therefore aids wayfinding.

Recently this correlation between localization, orientation and navigation has been challenged for mobile maps. Willis et al. [23] demonstrated that a mobile map affects the user's attention and hinders learning of spatial knowledge. They compared two groups that should learn the topography of a given space. One group had learned the environment from a map and the other from a mobile map. The mobile map group needed significantly longer time for this task because they had to simultaneously perform two effortful tasks that required conscious attention, i.e., learning the topography of the environment as well as observing the map during their exploration of the space.

Puikkonen et al. [14] argued that instead of incorporating automated positioning information, mobile support for indoor use should incorporate more landmark information. This information can be easily mapped from a mobile application to the physical surroundings. This is in line with observations made by Cosley et al. [4], who found that learning a spatial environment is hindered when the participant experiences it in a passive mode. Ramirez et al. [15] showed for the case of fire fighters, that it is more useful to support their spatial cognition and navigation practices rather than guiding them through predefined paths based on precise location information.

It is important to note that most of this work has been done on research prototypes. There are systems available for general use (e.g., Google Indoor Maps for selected locations in the US and Japan), but because indoor location-aware technology still requires mapping (or fingerprinting) of signals to locations onto a map of a specific building, and floor plans of buildings are often proprietary and not as standardized as road maps, many sites currently develop their own localization services and mobile map support for their own buildings.

3. METHODS

To answer our research question of whether self-localization indeed helps in such large, complex indoor environments, we tested a mobile application designed for the Paris Air Show at Le Bourget Airport, France. The Paris Air Show is a typical example of a complex environment for mainly in- as well as outdoor navigation. Reasons are the unfamiliarity of many visitors with the fair layout, the large number of exhibits (~2000 exhibitors), the large area covered (130,000 m2 of rented space), the need to move between multiple buildings, and crowdedness (~47,000 visitors per day).

A mobile application was developed specifically for the Paris Air Show by Insiteo, a company specialized in indoor navigation solutions. The functionality included an overview map of all halls and outdoor spaces (see Figure 1), several hall-specific maps of the fair (see Figure 2), a graphical visualization of the user's current position, graphical visualizations of the current locations of people who share their position with the application (the

Figure 1. The general map, zoomed in 2x to display the fair's main halls.

MeetMe feature), services such as route planning to a selected destination, and information about exhibitors at the fair.

The visualization of cues, i.e. the position of the user, the position of the destination in form of a pin, and the presentation of stand IDs follows state-of-the-art methods in mobile indoor navigation systems [19]. The application runs on HTC Desire (HD) Android 2.3 smartphones. The localization was done by matching the signal strengths of WiFi beacons measured by the phone to previously recorded 'fingerprint' data.

Figure 2. Screenshot displaying the map for hall 2B, with a pin marking the destination. The blue dot and compass symbol mark the user's location and orientation (going north).

3.1 Study Task Design

The study took place in Hall 2B, with one of the destinations located in hall 3. Figure 2 shows a screenshot of the map of Hall 2B, zoomed in on the area that participants used most frequently.

Participants were asked to perform 3 different tasks, where each task was composed of a number of subtasks. The tasks were designed to determine to what extent the system helped users to orient themselves, understand location information, and navigate through the fair. The tasks and subtasks were as follows:

Task 1: Find a stand within the hall

a) find information about the stand on the app
b) point to the stand from your current position
c) navigate to the stand

Task 2: Find and meet another person

a) locate and meet the person using the MeetMe feature
b) after you meet the person, take the provided paper map and put a mark where you think you are

Task 3: Find a stand in another hall

a) find information about the stand on the app
b) point to the stand from your current position
c) on the paper map, put a mark where you think the stand is located

For Task 1, the experimenter selected the destination stands, where it was made sure that the location was not already known to the participant and that all participants had to face a similar set of parameters with respect to distance and navigation complexity. For Task 2, participants had to find a member of the research team that they had already met during the introduction phase. For Task 3, the experimenter again selected the destination stand, ensuring that the participant had not already visited the location.

Task 2b and 3c explored to what extent people were able to apply knowledge gained from the mobile map to a paper map, which was provided by the fair organizer to all visitors. Because the paper map contained very little detail, and displayed the buildings at a different angle than the mobile map, these tasks were considered to be non-trivial.

3.2 Procedure

The participants were informed about the goal of the study. Each participant also got a short introduction on the features of the application to be used. Participants were informed that they were videotaped during the study. Each participant signed a consent form about the use of the collected data for scientific purposes and publication. Participants then filled in a pre-questionnaire with 20 questions about general personal information, their reasons for visiting the fair, their experience of navigating the fair, and their self-reported navigation skills.

Next, participants were provided with a phone, a HTC Desire HD (selected because of its large 4.3 inch touch screen), and asked to carry out the three tasks described earlier. All participants except one (who refused to be recorded) were captured on video during the study.

After completing the tasks, each participant filled in a questionnaire to evaluate the app in terms of usability and perceived usefulness, comparison of the app with other navigational aids, acceptance, and suggestions for improvements. Participants were rewarded with €15 for taking part in the study.

3.3 Participants

14 fair visitors (9 male, 5 female), aged between 20-54 (M=34.8, SD=12.6), were recruited for participation on site. The participants varied in nationality: 8 were French, 2 Dutch (of which 1 also half Italian), 1 Chinese, 1 Senegalese, 1 Moroccan, and 1 Indian. They had different professions, including 5 engineers/technicians, 5 students, 1 secretary, 1 budget coordinator, 1 project manager, and 1 unknown. All participants had received some form of higher education: bachelor's degree (9x), master's degree (3x), or professional education (2x). Three participants had little experience with smartphones, five had more than 12 months of experience, and five reported something in between. All participants indicated that they were familiar with Google Maps©, some also with other mobile map or location-based applications or automotive GPS systems.

4. RESULTS

In this section we present the quantitative and qualitative results gathered during the study. For each subtask we measured task duration and for the tasks that allowed for different levels of performance (Task 1b, 2b, 3b, and 3c), also the performance accuracy. We collected qualitative data in the form of the video recordings, and transcribed spoken comments. Finally, the questionnaire responses were collected from participants upon completion of all three tasks. We first present the quantitative data and then describe the different qualitative data sets in detail.

4.1 Technical Issues

Despite pre-tests on site, during which the system worked smoothly, we experienced technical problems during the study that affected the precision and timeliness of location updates. This caused temporary inaccurate positioning, temporary disappearance, or jumpiness of the localization symbol (as expressed by participant P7: *"It jumps too much … I'm sure I didn't jump!*"). The problems were found to be due to the crowdedness on both the WiFi and telecom networks during specific times of day (around lunch time). Those problems had an influence on the usability of the collected data (see the section on Task Timing and Performance below). However, in accordance with the findings of [8, 16], participants were easily able to correct potential misalignments between the cue(s) on the map and their mental map representation.

4.2 Task Timing and Performance

We timed each of the tasks manually with a stopwatch. We scored participants' performance on the subtasks *1b, 2b, 3b,* and *3c*. This was done by two observers who studied the video recordings of position, map app, and paper map, and agreed on a score between 1 and 5. Scoring was achieved according to the scheme shown in Table 1.

Table 1. Scoring scheme for accuracy of participants' actions.

5: very high accuracy	Pointing in the correct direction (within a 10 degree angle); drawing in the right location on the map (correct building and correct subquadrant, i.e., quadrant of a quadrant within that building).
4: high accuracy	Pointing at a 10-30 degree angle from the correct direction; drawing on the map in the right building, but neighboring subquadrant.
3: medium accuracy	Pointing at an angle of 30-60 degrees; drawing in the right building but neighboring quadrant.

2: low accuracy	Pointing at an angle of 60-120 degrees; drawing in the right building but in the opposite quadrant.
1: very low accuracy	Pointing at an angle of 120-180 degrees; drawing a location in a wrong hall on the map.

The resulting durations and participant performance scores are shown in Table 2. Some values of N in Table 2 are lower than 14 because one participant (P12) did not do the last two tasks because of delays during the first task and another (P7) could not perform Task 1c because the self-localization point did not show at that time. Technical issues, as already mentioned, prevented the performance of Task 2a in 5 cases.

Table 2. Duration (in m:s) and scores for the different tasks.

		Duration				Score			
Task	**N**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**
1a	14	0:10	3:48	1:08	1:09				
1b	14	0:01	4:00	0:58	1:05	1.0	5.0	2.57	1.22
1c	13	1:16	8:03	2:45	1:49				
2a	9	0:37	3:49	1:51	1:16				
2b	13	0:10	4:00	1:10	1:02	1.0	5.0	3.64	1.32
3a	13	0:20	1:35	0:47	0:22				
3b	13	0:02	2:50	1:02	0:57	1.0	5.0	3.46	1.51
3c	13	0:05	1:30	0:41	0:23	2.5	5.0	4.23	0.88

The task durations show remarkable variation, with some participants completing a task in just a few seconds, and others taking several minutes for the same task. Also in performance, strong variations were found. For task 1b (point to stand), all levels from 1 to 5 occurred at least once. In other words, participants aiming at the same destination actually pointed in many different directions, as illustrated by Figure 3. 11 participants scored 3 or lower, of which seven scored 2 or lower, indicating that this exercise was quite difficult for the majority of participants.

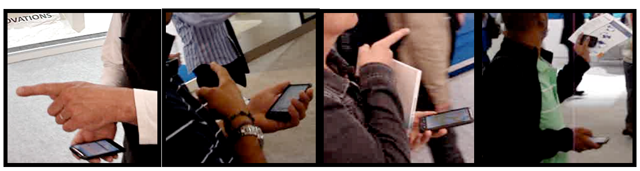

Figure 3. Four participants pointing during task 1b.

For task 2b (drawing own location on a paper map), two participants scored only 1. Three scored a 3. Nine scored a 4 or higher, of which three received the maximum score of 5. In short, a lot of variation, but on average higher scores for this exercise than the previous one.

For task 3b (point to stand in other hall), again, performance variation was observed, with five participants scoring 2 or less, three participants scoring between 3 and 4, and five participants scoring the maximum score of 5.

The last exercise, task 3c (on the paper map, put a mark where you think the stand is located) was performed best. Nobody scored less than 2.5, five scored between 4 and 4.5, and five scored the maximum score of 5. A participant performing this exercise is shown in Figure 4.

Figure 4. A participant performing exercise 3c, drawing the location of a stand in another hall on the paper map.

Considering individual differences, one participant (P10) consistently scored highly on all tasks, with a mean score of 4.75. Four participants scored quite low, with P9 scoring the lowest average score of 2.13. This indicates that there was a large gap between poor and optimal (but nearly attainable) performance.

4.3 Questionnaire Results

The post-study questionnaire contained 34 questions in total, related to evaluation of the navigation app in terms of usability, perceived usefulness of functionality, comparison with other navigational aids, acceptance, and suggestions for improvements.

General impression

Three questions asked about participants' general impression towards the system, its usefulness and helpfulness for navigating around the fair. Table 3 shows Median and Interquartile ranges for these Likert-scale questions (1-Very negative; 5-Very positive).

Table 3. Medians (MD) and inter-quartile ranges (IQR) for questions on the users' general impressions of the system.

Question	**MD**	**IQR**
1. Overall attitude towards the system	4	4-4
2. The system is very useful to me	4	3-4
3. The system helped me to navigate better around the fair	4	3.25-5

Most participants (11/14) had a positive attitude towards the system, where the rest were were neutral. Nine participants found the system useful, and ten participants found that the system helped them to navigate at the fair. Three people were slightly critical of the system's usefulness, and two were slightly critical of the system's helpfulness.

Functionality

Five questions asked about functionality and features of the system. Table 4 shows Median and Interquartile ranges for these Likert-scale questions (1-Not useful at all; 5-Very useful).

Table 4. Medians (MD) and inter-quartile ranges (IQR) for questions on system functionality and features.

Question	**MD**	**IQR**
4. Seeing your own location on the map	5	4.25-5
5. Finding the location of POIs	4.5	4-5
6. Finding other info about POIs	4.5	4-5
7. Planning a route to a POI	5	4-5
8. Finding another person's location (MeetMe)	4.5	4-5

All offered functionalities were regarded as useful by most participants (13/14). Few scores were lower than 4. Judging from the highest scores, the self-localization feature on the map was considered most useful, followed by planning a route to a Point-of-Interest (POI), finding the location of POIs and another person's location (Meet Me).

Comparison with Navigational Aids

We asked participants to rate different ways of gathering information for navigation on a usefulness Likert-scale (as described above). Their scores were then transformed to ranks. 10 participants rated the system as most useful, followed by the physical signs in the environment (9x), the large standing maps (6x), the paper map (4x), and talking to people face to face (3x). Talking to people on the phone was rated as least useful to find out where to go. If people preferred other navigational aids than the system, they either preferred a paper map or using no navigation aid *(P13: "Habit of finding one's way without help. My generation wasn't born with mannerist aids.").*

Task Difficulty

Three questions asked participants about the difficulty of the given tasks. Median and Interquartile ranges for these Likert-scale questions (1-Very difficult; 5-Very easy) are shown in Table 5.

Table 5. Medians (MD) and inter-quartile ranges (IQR) for task difficulty.

Question	MD	IQR
12. Difficulty finding own location	4	4-4
14. Difficulty finding destinations	4	4-4.75
16. Difficulty finding other people	4	3.5-5

Finding destinations (14/14) and one's own location (12/14) is considered relatively easy by most participants, although two found the latter reasonably difficult. Finding other people was judged very differently by the various participants, with some (8/14) scoring 4 or 5, and others (3/14) scoring 3 or lower.

Task Problems Encountered

Participants were asked whether they experienced any problems during the given tasks. For the task of finding out one's own location on the map using the system (Q13), participants mentioned that the localization pin on the map was changing (3x), that localization lacks precision (2x), the map does not rotate (1x), the orientation of the compass was not working (1x), the text on screen hindered orientation (1x), and that the current location was not always timely updated (1x). For the task of finding destinations using the system (Q15), one additional issue was reported, which is that the position of the localization pin disappeared sporadically. For the task of finding other people using the system (Q17), participants reported that self-localization on the map did not work correctly (3x), and that the position of the pin changes too fast sometimes, which is confusing (1x). One participant however was quite positive; P9: *"It was good and easy and user friendly… I could correct my direction easily."*

Interface Usability

Nine questions asked about the usability of the user interface, specifically focusing on the ease of use. Median and Interquartile ranges for these Likert-scale questions (1-Very difficult; 5-Very easy) are shown in Table 6.

The zoom feature was overall considered the easiest to use (14/14). The map of the fair area was mostly perceived as reasonably easy to use (9/14). Route planning was found to be relatively difficult to use by two people, and the Meet Me feature only by one. The interface was mostly perceived to be relatively easy to use (7/14), or very easy (6/14). Q25 asked about the need for help when using the system (see Table 6). This resulted in much variation, where some participants found they needed help to use the system (4/14), and others not at all (3/14). For perceived system response speed, most participants found it to be sufficiently responsive (11/14).

Table 6. Median (MD) and Inter-quartile ranges (IQR) for system usability, with a focus on ease of use.

Question	MD	IQR
18. Map of the fair area	4	3.25-4
19. Zoom in and out	5	4-5
20. Route planning	4	4-5
21. Info about POIs	4	4-5
22. Searchable index	5	4-5
23. Meet Me	4.75	4-5
24. Interface in general	4	4-5
25. System can be used without help	4	3.25-4.75
26. Perceived system response speed	4	4-4
27. Overall interface design (appearance)	4	4-4
28. System acceptance	4	3-5

User Suggestions

When participants were asked what they liked about the system (Q30), their responses included: interface ease of use (4x), overall interface (3x), application utility (3x), Meet Me feature for finding friends (2x), storing favorite locations (1x), application responsiveness (2x), similarity to existing systems (2x), learnability (1x), and enjoyable user experience (1x). However, participants found the following problematic: Imprecise localization (4x), problems with the Meet Me feature (2x), localization functionality failing (1x), system responsiveness (1x), touch screen sensitivity (1x), and map orientation (1x).

When asked for suggestions to improve the system (Q32), responses included: precision improvement (4x), speed/frequency improvement (2x), inclusion of a tutorial or guide with explanations (2x), showing complete map layout when moving to a specific hall (1x), better advertising of the app on site (1x), finding back favorited locations (1x), and improving map orientation (1x).

4.4 Video Transcript Case Analysis

The video recordings were transcribed, in terms of actions and spoken dialogue. Below we present dialogue and video examples for participant P9 (female, reasonable experience with smartphones, new to the fair). The examples outline a number of suboptimal navigation actions, insightful dialogue, and also interesting behavior during her interaction with the mobile phone, while she performed task 1b and 1c. The actual walking route and pointing actions are displayed in Figure 5.

She started off task 1b by pointing almost immediately (t=0:05) in the direction of the corridor (score = 3 out of 5, see arrow at location 0 in Figure 5, and Figure 6). At t=0:58, she said, while pointing at the pin on the map, *"If I'm facing this way, this is* *where they are situated, right? Ok. So what I'm saying is I should be walking this way (points straight). And this pinpoint, in my head, it should be in front of me, right, because it's in front of me."* Next, she focused on the screen rather than the environment. At t=2:10, she turned the phone around several times (180 degrees, 0 degrees, 90 degrees, 180 degrees, 90 degrees), commenting: *"I'm playing around, just changing it. I just wanted to see how it would situate me if I turned the phone. Because I don't necessarily have to hold it this way to tell me where I am. So if I turn it anyway, it should still tell me where I'm situated."*

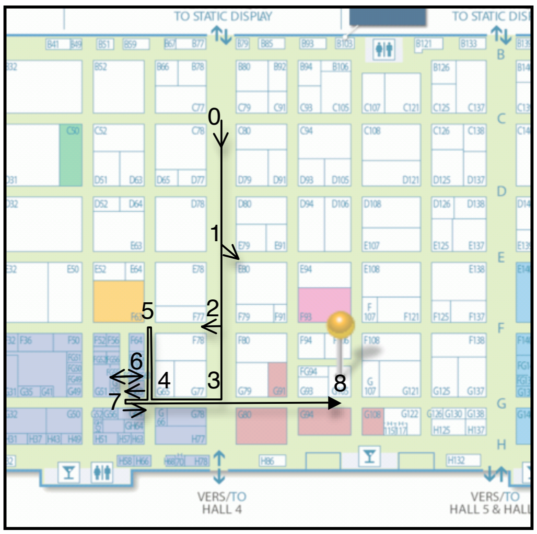

Figure 5. Walking route taken by participant P9, from start (0) to destination (8). Open arrows depict pointing actions.

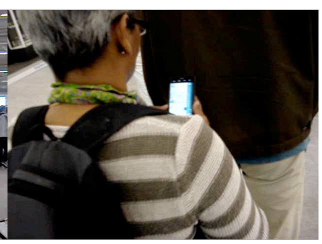

Figure 6. Pointing (task 1b). **Figure 7. Almost bumping.**

While walking (see Figure 5, location 1), she spontaneously pointed in the correct direction to the destination stand (about 45 degrees to the left). At point 2, a little further, she stopped and pointed 90 degrees to the right, however. She almost bumped into somebody at t=2:27, but kept looking at the phone (see Figure 7). Not until t=3:03, she looked up again from the phone. At point 3, she said: *"I'm at G, so it's on my right, is what I'm saying"* (which is 180 degrees wrong).

At t=3:40 and 3:52, while looking at the phone, she bumped into two different people, one of whom was reading a paper map. At point 4, she said *"I should be going this way",* turning right (still going away from the target). At point 5, she stopped and looked around the corner to the right, saying: *"It doesn't make sense"*. At point 6, she turned around, stopped for a while, and went back again. She pointed to the left and right along the G-aisle, saying *"It said it was in G, so it should be somewhere here"*. She pointed to the right, then turned right and started walking, towards point 7 (again, 180 degrees wrong). At point 7, she said: *"No, I'm going too far"*. She turned around, and pointed the right way, towards point 8, saying, *"I think I'm going away from it"*. From then on, she walked straight along the G-aisle, laughing and saying *"You might be walking around with me for the rest of the morning"*. Approaching the destination she suddenly looked up and stated, *"There it is"*, finally reaching the stand at t=6:06.

4.5 Behavior Analysis and Observations

From our observations and subsequent analysis of the video recordings, like the one described above, we found that the participants encountered several types of problems:

- Misinterpreting a destination's location on the mobile map in relation to the environment, exemplified by pointing the wrong way (see Table 1, task 1b and 3b);
- Difficulties in self-localization, evident when drawing on a paper map (task 2b);
- Wrong turns (12x in total, during task 1 and 2), e.g., turning right when it should be left, often followed by a self-correcting turn of 180 degrees (14x);
- Almost (9x) or actually (2x) bumping into other people, during task 1 and 2;
- Missing a turn (4x in total), or turning too soon (3x), leading to a suboptimal route (1x even leaving the hall);
- Although all participants were afterwards generally positive about the system and the study, 6 of them seemed very insecure while performing the tasks.

Furthermore, users displayed very different strategies in orientation, planning and path finding. 6 out of 14 participants transformed their navigation process into a game-like process where moving the self-localization dot to the destination pin on the phone's screen was the winning target. They were looking almost continuously at the phone's screen, and 3 of these 6 participants did not spot the destination stand until they had reached it. On the other hand, the remaining 8 participants were able to avoid this tendency, and alternated much more between looking at the environment, and at the phone. They either seemed to use a strategy of planning (and verbalizing) a route (3x), or making use of signs on the floor and ceiling (4x). Relatively more women (3/5) adopted the screen-fixating strategy than men (3/9), suggesting a possible gender effect, as found in other studies [7].

Considering the problems mentioned earlier (wrong turns, near and actual collisions, missing turns, turning too soon), the 6 participants with the strategy of fixating mostly on the mobile screen were more likely to experience problems than the other 8 (on average, 5.3 vs 1.7 problems per person, |2=16.85, df=2, $p<0.005$). The other 8 also reached their goal faster, as was shown for task 1c.

Two of the problems mentioned above were related to the current interface design of the system used:

- The current compass symbol (see Figure 2) led to misinterpretations by some participants with respect to their own position, causing them to point or walk in the opposite direction of their destination. This clearly indicates that a localization icon that also provides information about the user's orientation needs to be carefully designed. More importantly, it also indicates that the fixation and reliance on the virtual map representation of the fair space hinders an active construction of the actual physical environment.
- Several participants mentioned they would like the map to rotate when they change direction (similar to Google Maps Navigation [5]), so that their orientation is always facing up on the display. Some participants expressed a strong preference for static maps with the North facing up, however.

As this clearly influences the ability of users not only to navigate but also orient themselves, a mobile map system needs to be able to adapt to the user's preferences.

5. DISCUSSION

If one looks only at whether people find their destination and whether they are content with the system, one gets very positive results, as the questionnaire results indicate. However, upon closer inspection, people encounter several kinds of problems during the various tasks, including mistakes during navigation, and in particular during the initial orientation phase. There is a large variation in performance between individual cases, despite that all participants were given our system as a navigational aid.

The misinterpretation of the compass symbol and the lack of orientation-up display may be part of the reason for some of the navigation failures. These issues should be addressed in future versions of the interface by redesigning the compass symbol in a way that is not ambiguous, and allowing both automatic rotation and north-up display of the map. Seager and Fraser [18] found that physically rotating a phone displaying a steady map works better (in terms of navigation errors and mental workload) than automatic rotation of the map on the phone. In our study, only five participants were physically rotating the phone occasionally. Perhaps participants were afraid of dropping it (as in Seager and Fraser's study), or the phone's dimensions made it difficult to rotate it.

Overall, it appears that many of the observed navigational errors stem from a general failure of associating one's own view of the map with the perception of one's immediate environment. The provided map reduced the environment to a simple set of shapes and only provided letter-number combinations as identifiers for stands, which may have made it hard to relate the contents of the map to the surroundings. This difficulty is further amplified by the hectic fair environment that depletes users' already limited attentional and memory resources [20]. This may be partially alleviated by adding pictures or pictographic icons of landmarks in the nearby surroundings to the map in order to support orientation. Puikkonen et al. [14] suggest that part of the design of the digital map should be done in situ in order to achieve better consistency between the map and the environment in terms of basic features such as colors, shapes and materials. However, this is difficult to achieve in large indoor exhibition centers, as they often do not have many large architectural landmarks as reference points. Also, there is only a short time for development once the fair layout is determined for a particular fair, which makes thorough preparation for in situ design difficult. Nevertheless, some markers at fairs do exist, and more attention should be given to ensuring a general consistency between not just the mobile map and the environment, but also between provided paper maps, large standing maps, and signs within the building [19].

The current interface design seems to stimulate users to focus mostly on the movement of the self-localization dot on the screen representing their own location (and that of the person to meet). This was highlighted by one of the participants (P9: *"I realized that you don't need to think much when using navigation systems. You just avoid going in the opposite direction")*. Although participants were able to reach their goals due to this feature and were generally positive about the system, we believe the current system demonstrates two general shortcomings of the dominant visual paradigm of self-localization on a mobile map.

First, although people are capable of finding both static as moving destinations, their scores vary widely on orientation tasks, i.e., pointing to their destination, or indicating where they have ended up after using the system. This indicates that navigation aids do not necessarily support the orientation phase preceding or following actual navigation, and that these phases may need different means of support. Schmid et al. [17] show that reducing the level of representational detail on a map can achieve better orientation, but they focus on outdoor rather than indoor applications. Futher experiments are needed to test whether varying the representational detail on a map (i.e., number of landmark symbols) could also support orientation in large, complex indoor environments.

Second, we noticed many instances of inattentional blindness [9], where several people focused so much on the screen to the point of diminished awareness of their surroundings. In these cases, participants spotted their destination only shortly before they reached it, and occasionally (almost) collided with other people. One participant expressed this concern explicitly (P11: *"You risk having your eyes on the phone all the time. You then benefit less from the surroundings!")*. Related work focusing on bumping into things while *talking* on a mobile phone could not confirm that this increases the likelihood of collisions [21], but our results suggest more research is needed on the detrimental effects of *looking* at a phone while carrying out other tasks. A mobile map with automated position information seems able to draw so much attention away from the environment that users can get 'lost in navigation'. For tasks where orientation plays an important role, this tendency towards screen fixation needs to be limited somehow. This could for example be done by providing the bare minimum route information, such as directions to the next landmark that is within visual reach.

Our results suggest that navigation and orientation are not as tightly coupled as described in the traditional wayfinding literature [1, 22], and furthermore may require different forms of mobile support. Different wayfinding tasks may be served by other modalities such as audio [10] or haptic feedback [13], instead of, or in combination with visual maps.

In order to guide navigation from point A to B, information in the visual modality seemed to suffice for our users. Since the system was found to decrease awareness of the fair's surroundings, information supporting navigation (such as directions, or distance information) might be presented in other modalities, in particular haptics [13]. Field studies of haptic systems will be necessary to determine if they indeed support navigation in complex indoor environments, whether they are accepted by the general public, and to what extent they allow more attention to be spent on the surroundings.

In order to support orientation and route planning however, the visual modality currently remains the best option. Since orientation still provides problems for current visual map interfaces, it remains an open question how to support orientation with audio or haptic information, alone, or in combination with visual information. We imagine that future support for wayfinding might combine information in different modalities for different wayfinding tasks, e.g., use visual information to convey information about points of interests and support (collaborative) route planning, use auditory information (speech or sonification [10]) to convey locations or directions when these do not interfere with other auditory information in the environment, and use tactile information (e.g., a haptic belt) to aid orientation to support body alignment with the map, or give navigational directions when visual and auditory channels are busy elsewhere [12]. How to integrate and balance these resources depends on the demands of specific settings, and personal navigation strategies.

6. CONCLUSIONS & FUTURE WORK

To evaluate a mobile indoor map-based support system we have carried out a field study with 14 visitors at the Paris Air Show.

The results of the questionnaire were generally positive for all functionalities of the system, including self-localization, finding the location of points of interest, route planning, finding extra information, and finding another person's location. However, findings from the study indicated that users encountered serious difficulties during the various orientation and navigation tasks. Most importantly, they had trouble identifying the correct direction from consulting the mobile map, which indicated that the current paradigm of self-localization on a map is insufficient for supporting users in acquiring a sense of orientation in large indoor environments. In six of the 14 cases, much attention was allocated to the mobile screen, resulting in diminished awareness of the participants' surroundings, and more navigation mistakes. To address this, care should be taken on giving the right amount of representational detail on a map, the role of the mobile phone's form factor for map rotation, and the possibility of providing eyes-free interaction to maintain awareness of surroundings.

In future work, we will address the shortcomings of the current system by (1) improving on technical issues such as localization imprecision, (2) improving support for the orientation phase by experimenting with varying representational detail on a map, and (3) investigate eyes-free interaction methods, in particular, haptics, for the navigation phase, and in combination with visual maps, for the orientation phase. By disentangling the needs related to the processes of orientation and navigation, we aim to ultimately provide a better mapping between needs and presentation modes to establish adequate support for wayfinding in large, complex indoor environments.

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8. REFERENCES

[1] Arthur, P., and Passini, R. (1992). Wayfinding: People, signs and architecture. McGrawHill, New York.

[2] Bouwer, A. J., Nack, F., and Evers, V. (2011). Towards Support for Collaborative Navigation in Complex Indoor Environments. In Proc. of CSCW 2011, ACM, 601–604.

[3] Chen, J., and Stanney, K. (1999). A theoretical model of wayfinding in virtual environments: proposed strategies for navigational aiding. Presence, 8(6), 671–685.

[4] Cosley, D., Baxter, J., Lee, S., Alson, B., Nomura, S., Adams, P., Sarabu, S., and Gay, G. (2009). A tag in the hand: supporting semantic, social, and spatial navigation in museums. In Proc. of CHI '09. ACM, 1953–1962.

[5] Google Maps Navigation. Retrieved on 20 Aug. 2012 from: http://www.google.com/mobile/navigation/.

[6] Hölscher, C., Büchner, S. J., Meilinger, T., and Strube, G. (2009). Adaptivity of wayfinding strategies in a multi-building ensemble: The effects of spatial structure, task requirements and metric information. Journal of Environmental Psychology, 29, 208–219.

[7] Lawton, C. A. (1996). Strategies for indoor wayfinding: The role of orientation. Journal of Environmental Psychology, 16, 137–145.

[8] Levine, M. (1982). You-are-here maps: psychological considerations. Environment and Behavior, 14, 221– 237.

[9] Mack, A., and Rock, I. (1998). Inattentional Blindness. MIT Press, Cambridge, Massachusetts.

[10] McGookin, D., Brewster, S., and Priego, P. (2009). Audio Bubbles: Employing Non-speech Audio to Support Tourist Wayfinding. In Altinsoy, M., Jekosch, U., and Brewster, S. (eds.), Haptic and Audio Interaction Design, Lecture Notes in Computer Science, Vol. 5763, 41-50, Springer, Berlin.

[11] Nurmi, P., Salovaara, A., Bhattacharya, S., Pulkkinen, T., and Kahl. G. (2011). Influence of landmark-based navigation instructions on user attention in indoor smart spaces. In Proc. of IUI '11. ACM, 33–42.

[12] Pielot, M., and Boll, S. (2010). Tactile Wayfinder: Comparison of tactile waypoint navigation with commercial pedestrian navigation systems. In Floréen, P., Krüger, A., and Spasojevic, M. (eds.), Pervasive computing. Springer, Berlin, 76–93.

[13] Pielot, M., Poppinga, B., and Boll, S. (2010). Pocket-Navigator: vibro-tactile waypoint navigation for everyday mobile devices. In Proc. of MobileHCI '10. ACM, New York, 423-426.

[14] Puikkonen, A., Sarjanoja, A., Haveri, M., Huhtala, J., and Häkkilä, J. (2009). Towards designing better maps for indoor navigation: experiences from a case study. In Proc. of Mobile and Ubiquitous Multimedia (MUM '09), ACM.

[15] Ramirez, L., Denef, S., and Dyrks, T. (2009). Towards human-centered support for indoor navigation. In Proc. of CHI '09. ACM. 1279–1282.

[16] Rossano, M. J., and Warren, D. H. (1989). Misaligned maps lead to predictable errors. Perception, 18, 215– 229.

[17] Schmid, F., Kuntzsch, C., Winter, S., Kazerani, A. and Preisig, B. (2010). Situated local and global orientation in mobile you-are-here maps. In Proc. of MobileHCI '10, ACM, New York, 83-92.

[18] Seager, W. and Fraser, D. S. (2007). Comparing physical, automatic and manual map rotation for pedestrian navigation. In Proc. of CHI '07. ACM, New York, 767-776.

[19] Taher, F. and Cheverst, K. (2011). Exploring user preferences for indoor navigation support through a combination of mobile and fixed displays. In Proc. of MobileHCI '11. ACM, New York, 201-210.

[20] Thorndyke, P. W., and Hayes-Roth, B. (1982). Difference in spatial knowledge acquired from maps and navigation. Cognitive Psychology, 14, 560–589.

[21] Tractinsky, N. and Shinar, D. (2008). Do we bump into things more while speaking on a cell phone? In Proc. of CHI '08 Extended Abstracts, Alt CHI. ACM, New York, 2433-2442.

[22] Warren, D.H. (1994). Self-Localization on Plan and Oblique Maps, Environment and Behavior, 26:1, 71-98.

[23] Willis, K. S., Hölscher, C., Wilbertz, G., and Li, C. (2009). A comparison of spatial knowledge acquisition with maps and mobile maps. Computers, Environment and Urban Systems, 2009: 100–110.

[24] Yao, X. (2007). Pedestrian navigation systems: a showcase for deep personalization theory. In Proc. of MobileHCI '07, vol. 309. ACM, New York, NY, 174-177.