Augmenting Audio Messages with Visual Directions in Mobile Guides: an Evaluation of Three Approaches

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ABSTRACT

Supporting users' navigation is a fundamental feature of mobile guides. This paper presents an experimental evaluation comparing three different ways of providing navigation guidance by combining visual and audio directions during guided city tours. The three considered solutions differ in the way audio directions are augmented with visual directions: a traditional map-based solution, a combination of a map and photographs of the area, a combination of large arrows and photographs. The results of our evaluation show that when the map is combined with photographs that clearly indicate the direction to the user or when the map is replaced by a combination of directional arrows and photographs, users' performance is significantly better. Moreover, the combination of map and photographs was highly preferred by users.

Categories and Subject Descriptors

H.5.2 [**Information interfaces and presentation**]: Evaluation, screen design, Graphical user interfaces (GUI); I.3.6 [**Computer Graphics**]: Interaction techniques

General Terms

Human Factors, Experimentation

Keywords

Mobile guides, navigation aids, evaluation

1. INTRODUCTION

In recent years, there has been a growing interest towards the development of *mobile guides* [3], i.e. mobile systems exploiting portable, lightweight devices (such as PDAs or high-end mobile phones) to guide users in different environments (cities, museums, fairs, etc.) and provide them with useful information and services. These guides often take into account contextual information such as physical location of the user, time of day, weather, and user's preferences and interests. Different classes of users (e.g., tourists, businesspersons, rescue personnel, etc.) can thus access different kinds of services (e.g., navigation support, information delivery, route planning, etc.) and benefit from up-to-date information.

Since supporting users' navigation is a primary goal of most mobile guides, designing an interface that best fulfills this requirement is fundamental. This is challenging because, besides limitations of mobile devices, one has to consider that navigation is often not the primary task for the user and thus cognitive resources required to use the guide should be limited. Audio directions are typically used in map-based guides to reduce the time the user has to look at the display. In this paper, we experimentally compare three different ways of combining audio and visual directions. The first is a traditional map-based solution, the second alternates photographs of the environment and map indications, the third alternates photographs and large arrow indications.

The paper is organized as follows. Section 2 surveys related work on providing directions in mobile guides. Section 3 describes the considered solutions. In Section 4 and 5, we describe the experimental evaluation we carried out and report about the results we obtained. Finally, Section 6 contains concluding remarks.

2. RELATED WORK

2.1 Mobile Guides

Much research has been carried out on mobile guides since the first pioneering prototypes, developed in the Cyberguide [1] project. Mobile guides have evolved into complex systems, providing users with an increasing number of services. Systems such as GUIDE [4, 7, 8] and Lol@ [25] provide users with relevant context-aware information about the area being visited in a city (such as the location of attractions, restaurants, etc.) and give users the opportunity to follow guided tours. Many mobile guides provide route planning information and directions for wayfinding (e.g., [10, 17, 28]). Specific mobile guides have been also developed to provide information and navigation assistance in fairs (e.g., [16, 32]), museums (e.g., [11, 29]), public transportation (e.g., [19]), or even to support user's social life (e.g., [21, 26]).

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2.2 Providing Directions in Mobile Guides

Different techniques are used by mobile guides to provide route directions. Kray et al. [22] identify the following ones:

- *Text*: a series of textual instructions.
- *Speech*: a series of spoken instructions.
- *2D Route Sketches*: qualitative abstract forms, e.g. properly oriented arrows.
- *2D Maps*: 2D electronic maps of the area that usually highlight the path to follow and the current position of the user.
- *3D Maps*: visualizations of the area in three-dimensional computer graphics.

Considering very recent research developments [14], we can add the following technique:

- *Photographs*: visualization of photographs of the places the user has to head towards.

Current systems tend to combine different techniques, taking advantage of their specific properties e.g. to deal with different users, available resources and contexts of use.

Textual instructions are the least demanding in terms of technical resources and can be combined with all other techniques. However, when the current location and orientation of the user are not precisely known or the surrounding environment is complex, long descriptions are needed to give directions (because the context must be explicitly described) and this quickly increases the cognitive load on the user.

Providing audio directions can decrease navigation time, as shown in [9]. Moreover, employing audio directions reduces the time the user has to look at the screen of the mobile device to obtain navigation information. Both speech and non-speech audio have been investigated to provide navigation assistance in the case of normally sighted users and also in the case of visually impaired users [13, 17, 20]. Audio directions suffer from the same limitations of textual instructions when complex descriptions must be provided.

The use of route sketches in the form of arrows is familiar to users of car navigation systems and can be ideal for users with limited orientation and map-reading abilities. As reported in [22], the main advantage of this technique is also its limitation since its high level of abstraction helps to reduce cognitive effort but removes information that would help a user to find her way. Moreover, since GPS devices for PDAs are typically not equipped with an electronic compass, the orientation of the user must be derived via software and is sometimes inaccurate (when the GPS signal is poor) or unavailable (when the user is not moving). It is thus necessary to combine this technique with others.

2D maps are the most common approach in mobile guides. However, using a map for orientation implies a significant mental effort (as with a paper map) to switch between the egocentric perspective of the viewer and the geocentric perspective of the map. This effort is smaller if the map is forward-up (the orientation of the map remains static with respect to the world, i.e. the forward direction in the world is always at the top) rather than north-up (the orientation of the map remains static with respect to the viewer, i.e. the north is always at the top). Indeed, as shown by various studies (e.g., [15, 32]), the number of navigational errors decreases with a forward-up map compared to a north-up map. Moreover, forward-up maps allow users to better understand their orientation and to reach targets faster [31]. Unfortunately, precise automatic alignment of forward-up maps requires an electronic compass. Research on the design of map representations for mobile devices is presented in [12, 35]. Some results on map generalization have also been used to deal with the problem of map visualization on small displays to abstract irrelevant details and reduce the cognitive effort of the user (e.g., [2, 34]).

Some attempts have also been made at exploring the use of 3D graphics for mobile guides to better support navigation and information access (e.g. [5, 23, 24, 27]). Rakkolainen et al. [27] found that 3D models help users to recognize landmarks and find routes in cities more easily than traditional 2D maps. Laakso et al. [24], on the other hand, found that 3D maps were slower to use both in initial orientation and route finding compared to 2D maps although users liked the 3D maps. This approach also requires powerful hardware and is the most difficult and time-consuming to implement.

The approach based on photographs is still rarely employed in mobile guides although it could provide quite good navigational support by simplifying visual recognition of landmarks. It is slightly more difficult to implement compared to the other approaches (except 3D maps) because it requires to accurately select and acquire the most appropriate photographs. However, it has the additional advantage of depending only weakly on the actual direction of the user, thus being useful even when position and orientation information is inaccurate. This solution has been employed, for example, in the GUIDE project [8] to help users determine their location.

2.3 Experimental Studies on Pedestrian Navigation Support

Many mobile guides have been evaluated on users (e.g., [8, 18, 24, 25, 33]), often to obtain feedback and produce improved prototypes. Although it is less common with respect to other domains such as car navigation systems (e.g., [6]) or virtual environments (e.g., [9]), some studies compared different navigation support features. Laakso et al. [24], as previously reported, compared 2D and 3D maps. Ross et al. [30] investigated the use of landmarks in pedestrian navigation support, demonstrating that it raises users' confidence and reduces errors. Goodman et al. [14] studied the effectiveness of different methods for presenting landmark information to older people. The first part of the study investigated whether pedestrian navigation support combining together text, speech and photographs could be effective for older adults compared to the use of a paper map. The second part compared the effectiveness of different methods for presenting landmark information, namely text, speech and text+speech. Results showed that all techniques were effective for presenting landmark information.

3. THE CONSIDERED SOLUTIONS

We implemented and compared three different solutions to support users' navigation along a guided tour. All solutions augment audio directions with different types of visual information: the first is a traditional map-based solution, the second alternates photographs of the area and map indications, the third alternates photographs and large arrow indications. We aimed at testing solutions that could be effectively used in mobile guides. Indeed, as previously discussed, audio instructions have the advantage of not requiring visual attention but they must be kept simple to avoid increasing cognitive load. Since there can be situations when directions are too complex to describe only through audio (e.g., when there are many possible alternative directions) or when the provided indications are not sufficient for the user, visual techniques can be added to provide users with the necessary information. We employed simple speech messages that provided directions with respect to the current position of the user (e.g., “Turn left at the next crossroad”, “Go along this street”, etc.).

The combinations of visual information we chose were motivated by different considerations. First, textual instructions were discarded because they suffered from the same problems of audio instructions. 3D maps were discarded as well because they need too many resources (which may not be available in many mobile devices) and because they are too complex and costly to implement in a realistic mobile guide (e.g., 3D modeling of a whole city). The 2D map was instead considered because it is the most common approach in current mobile guides. We then decided to evaluate if photographs (augmented with perspective arrows to indicate direction) can be combined with a map to improve user’s navigation support or if they can be combined with 2D arrows that replace the map. We assumed the availability of a GPS device but we did not assume the availability of an electronic compass, since it is not common in PDAs. This forced us to develop a specific algorithm that analyzes the sequence of user’s positions to determine the direction of the user along a tour.

The above described visual indications have been tested on a fully functional location-aware mobile guide that allows users to choose a predefined tour from a list of available tours, supports user’s navigation by means of visual and audio indications, and provides information on points of interest through the use of videos, speech audio and rich HTML pages. The guide provides indication of the completed percentage of a tour by means of a progress bar (see the top part of Fig. 1, 2 and 3) and a numeric indication of the distance to be traveled (see bottom part of Fig. 1, 2 and 3). The strength of the GPS signal is indicated through a familiar metaphor from mobile phones.

Unlike the study in [14], where users had only to navigate routes following the provided directions, we engaged users in a real tour, where they could obtain information on points of interest (after reaching them) by reading descriptions, listening to audio clips and watching videos. This is consistent with the typical use of a mobile tourist guide.

3.1 Map Condition

In the Map condition, a map on the screen (Fig. 1) visualizes the path the user has to follow as a (blue) line and the path the user has already completed as a (gray) bold line. However, due to the richness in information it usually provides, the map can be used even when the GPS provides inaccurate data. The map is forward-up and includes street names, points of interest (represented by red flags), starting and ending points (represented by green flags) of the tour. The user can pan and zoom the map to look at specific areas and a button (Fig. 1, bottom right) allows the user to center the visualization on the current position.

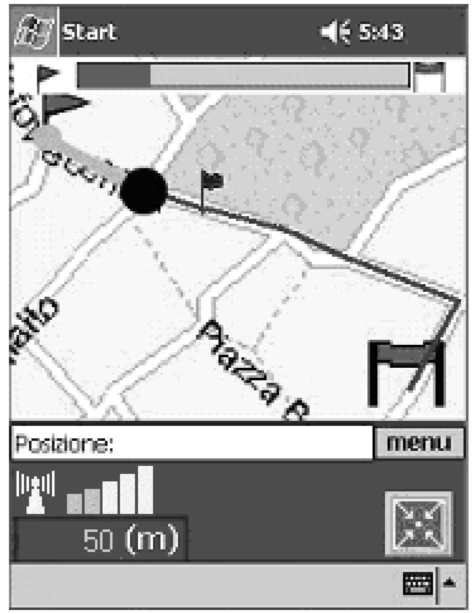

Figure 1: Map

3.2 Map+Photographs Condition

In the Map+Photographs condition, the screen alternates between the display of the map (Fig. 1) and photographs that include perspective arrows to indicate direction (Fig. 2).

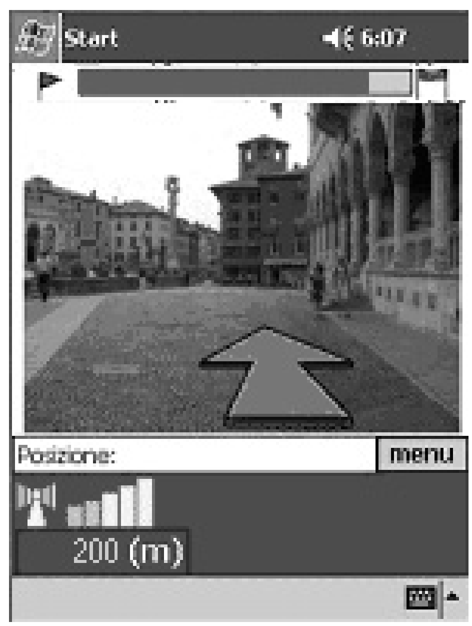

Figure 2: Photographs

The map is displayed while the user is walking, while photographs are displayed (replacing the map on the screen) in the following situations:

1. At the starting point of the tour.

2. When approaching crossroads.

3. When proceeding in the tour after reaching a point of interest and obtaining information about it.

Photographs disappear a few seconds after the user has started to move.

3.3 Arrows+Photographs Condition

In this condition, the map has been replaced by large black arrows (Fig. 3) that show the direction to follow. Photographs (Fig. 2) are shown in the same situations described for the Map+Photographs condition.

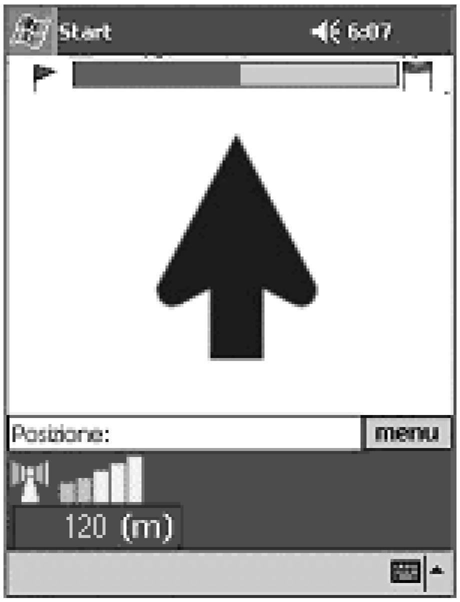

Figure 3: Arrows

4. EXPERIMENTAL EVALUATION

The evaluation has been carried out in the historic center of the city of Udine, Italy. The chosen area is mostly reserved to pedestrians and thus particularly interesting for using mobile guides.

4.1 Subjects

Twelve tourists, 7 male and 5 female, took part in the evaluation. Their age ranged from 20 to 40, averaging at 28. None of them had ever visited the city before. Only two of them had experience with computers. Two of them described themselves as having significant experience with maps, 4 as having sufficient experience and 6 as having no experience at all. Finally, only two of them had used a PDA before (and only occasionally). As a reward for participating in the experiment, each tourist received a free lunch in a city restaurant.

4.2 Hardware

The evaluation was carried out using a Casio Cassiopeia E200I. Power saving features were disabled to provide maximum performance. The device had 64 MB of internal memory and the mobile guide needed an additional 32 MB Secure Digital memory card. The GPS device was a PRETEC Compact Flash GPS card equipped with an external antenna. Audio was delivered by an earphone. Figure 4 shows the employed hardware.

Figure 4: The hardware used in the evaluation

4.3 Design and Procedure

Each subject was asked to follow the directions provided by the mobile guide and complete a preset tour. According to a within-groups design, each subject carried out the task in each of the three conditions. We thus had to prepare three different tours to prevent learning effects due to the acquisition of navigational knowledge. The tour paths (illustrated in Fig. 5) had the same length (230 meters), the same number (and complexity) of streets and crossroads, and the same number of points of interest.

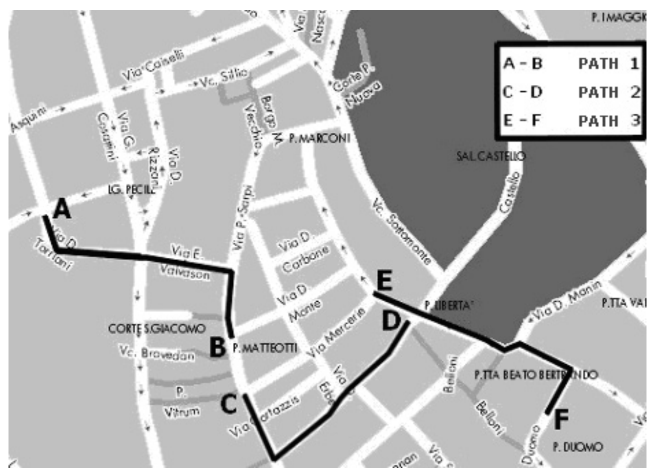

Figure 5: The three paths used in the evaluation

In choosing the paths, we also took care in guaranteeing the availability of a sufficient GPS signal all along each path. To do so, we acquired GPS data in the city center over a period of two days. Initially, we chose 10 paths having the same length and complexity, and identified 23 points on each path, with a distance of 10 meters between subsequent points. At each point, we acquired the number of available satellites. We then computed the average number of satellites for each point and for each path over the two days. The best three paths (Fig. 6) with an average number of available satellites greater than 4 have then been chosen for the evaluation.

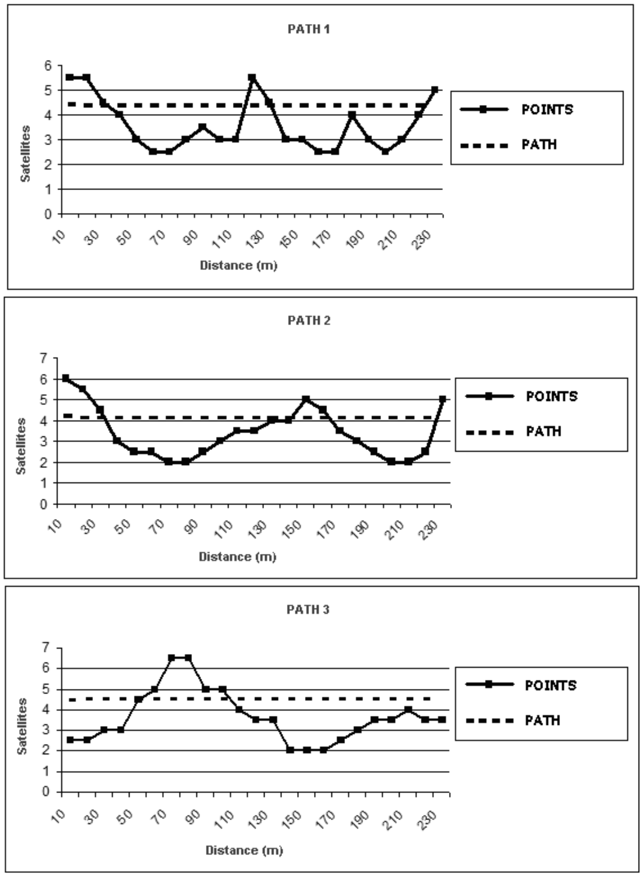

Figure 6: Average number of available satellites for the three paths used in the evaluation

The order of execution of the three tours and the order of the three conditions changed independently for each subject in such a way that:

- Every condition was presented an approximately equal number of times as a first, second, and third condition.
- Every path was covered an approximately equal number of times as a first, second, and third path.
- There was no fixed association between a specific tour and a specific condition (to counterbalance the effects of a possibly higher navigational difficulty of a tour over the others, in case the effort to keep complexity of the three paths constant might have left something unaccounted for).

Subjects were initially asked to fill a questionnaire containing demographic questions (age, sex, computer experience, PDA experience, etc.). They were then led at the beginning of one of the tours and were explained the task. Before starting the actual test, subjects went through a short training session lasting about 10 minutes to learn how to use the mobile guide and the three types of visual instructions. This step ended when subjects felt ready to use the guide. Each subject then followed the three tours. Each tour started with an initial presentation provided by the guide. Users had then to tap on a "Start" button to begin the tour and follow the directions provided by the guide. During the tour, the guide asked the user to stop at points of interest and provided information about them during the stop. When users wanted to continue with the tour, they tapped on a "Continue" button. The experimenter discreetly followed and observed subjects, walking a few meters behind them to avoid influencing their navigation and gathering times by means of a stopwatch. A second questionnaire was administered after subjects had completed the three tours to collect data about subjective impressions and preferences. On average, the time needed to complete the evaluation for each subject was around an hour.

The following dependent variables were measured:

1. Orientation Before Walking time: the total time needed by subjects to decide how to proceed along the guided tour after stops. To determine when to start and when to stop measuring this time, we identified the following situations:
   - Start of tour: at the beginning of a tour, we recorded the time elapsed from the instant a subject tapped on the 'Start" button (after having listened to the initial presentation of the tour provided by the guide) to the instant she started walking.
   - Points of interest: during the tour, we recorded the time elapsed from the instant a subject tapped on the 'Continue Tour" button (after having listened to the information on a point of interest) to the instant she started walking.
   - Other stops: during the tour, we recorded the time elapsed from the instant subjects stopped walking to look at the provided directions to the instant they began walking again.
2. Walking time: the total time spent walking.
3. Number of errors: we counted an error when a user deviated from the correct path for more than 5 seconds or told the experimenter that she was unable to orient herself (in both cases, the experimenter indicated the right direction).

Note that the time spent by subjects to listen and look at the information about points of interest (presented during the stops at those points) is not considered in the following analysis because it was not influenced by the way navigation directions were provided.

5. RESULTS

5.1 Times and Errors

We performed a one-way repeated measures ANOVA on the Orientation Before Walking and on the Walking times, with the type of visual directions as independent variable. The values of means for the Orientation Before Walking and for the Walking times are respectively illustrated in Fig. 7 and Fig. 8.

For Orientation Before Walking, the ANOVA pointed out that the effect was significant ($F(2, 22) = 39.82$, $P < 0.0001$). We thus employed the Tukey test for post-hoc comparison among means. It turns out that the Map condition was significantly worse than the other two conditions ($P < 0.001$),

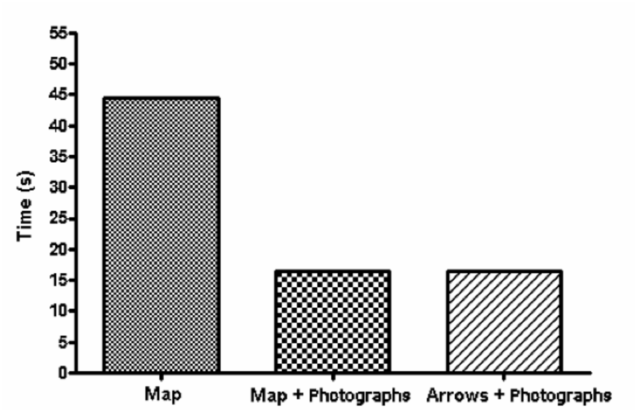

Figure 7: Orientation Before Walking (mean times)

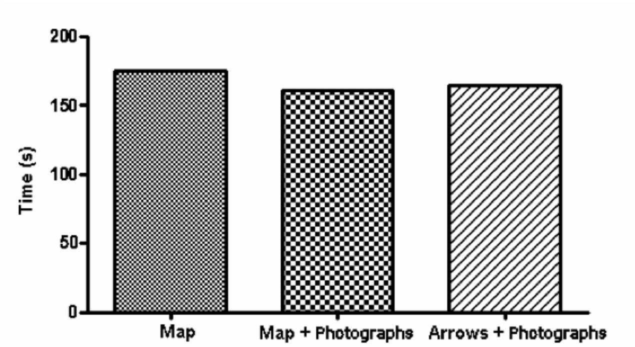

Figure 8: Walking (mean times)

while there was no statistically significant difference between Map+Photographs and Arrows+Photographs conditions.

For the Walking times, the ANOVA pointed out that the effect was not significant ($F(2, 22) = 1.315$, $P = 0.2888$).

To analyze the data on the number of errors we employed Friedman's test. Globally, three errors were made in the Map condition, one error in the Map+Photographs condition and no errors in the Arrows+Photographs condition. Means are shown in Fig. 9. The analysis showed that the effect was not significant ($T = 3.5$, $P = 0.1738$).

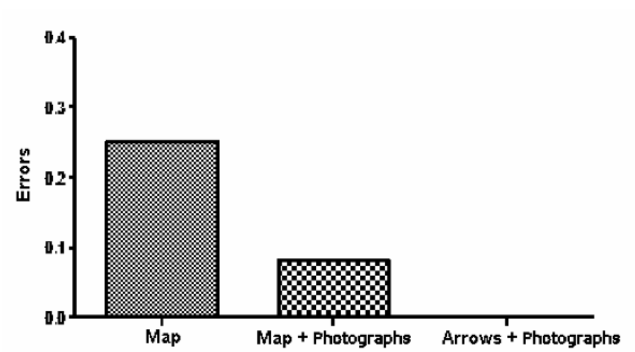

Figure 9: Mean number of errors

The following remarks can be made:

- Since only photographs were used in both the Map+Photographs and Arrows+Photographs conditions to provide directions after users stopped and before they walked again (indeed, the map and the arrows were respectively shown only after the user started walking in a specific direction), photographs (augmented with perspective arrows) allow users to understand directions more quickly with respect to using a map. This is probably due to the fact that it is simpler for the user to match a photograph with a view of the physical world rather than switching between the geocentric perspective of the map and the egocentric perspective of the world (and viceversa) to obtain directional information.

- While walking, subjects tended to rely mainly on the audio instructions provided by the guide and to look from time to time at the screen of the device only to make sure they were going in the right direction. This may explain why there were no statistically significant differences among the three conditions.

- The lack of a significant effect in the analysis of the mean number of errors and the overall low number of errors indicate that the combined audio and visual directions were similarly effective in conveying the right information.

5.2 Preferences

In the final questionnaire, users were asked to state their preference for one of the conditions. Eight users preferred the Map+Photographs condition, 3 preferred the Arrows+Photographs condition and 1 the Map condition. A Chi-Square test highlighted that the difference was statistically significant ($\chi^2 = 6.5$, $p = 0.038$).

This result shows that users highly prefer the combination of photographs and map to support navigation during a guided tour.

Users were also asked to give a vote on a 5-values Likert scale (where higher values corresponded to better ratings) to the usefulness of the map, the photographs and the arrows employed by the mobile guide. Means are graphically illustrated in Fig. 10. Friedman's test on this data pointed out that there was a statistically significant effect ($T = 12.19$, $P = 0.0023$). We thus employed Dunn's test for post-hoc analysis. Results highlighted that there was a statistically significant difference between photographs and arrows ($P < 0.01$) while there was no significant difference with other pairs of conditions.

5.3 Users' Comments

The final questionnaire also allowed users to provide free feedback. In general, users expressed their appreciation for the combination of audio and visual directions. Users liked the use of audio indications because it allowed them to navigate the environment without having to continuously look at the PDA display and they liked visual indications because they were useful to increase their level of confidence during navigation.

Some users suggested to show the photographs in the same screen as the map and not full-screen. For both conditions using photographs, some users complained that some of the images were taken from a different perspective compared to the actual position of the user.

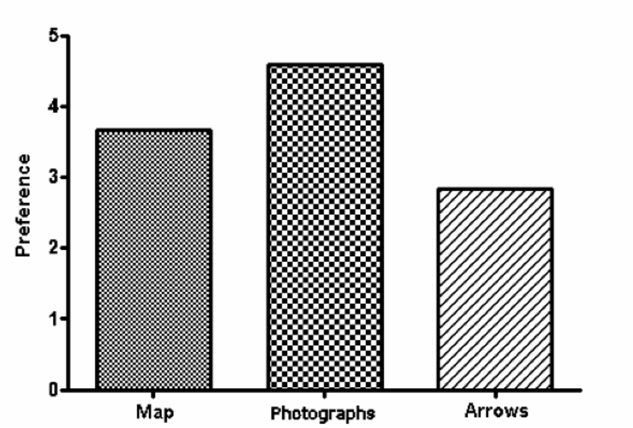

Figure 10: Perceived usefulness of map, photographs and arrows (means)

Users provided also some general comments about the mobile guide. They liked the push approach used by the system, i.e. information is automatically presented to users when they reach points of interest, but complained about the guide starting to describe points of interest without first providing indications of where the objects were in relation to the user's position. Users would have preferred more feedback from the system about aspects such as the lenght of the audio clips or an estimate of the time needed to complete a tour. Some users asked for the possibility to access more services such as weather forecast. It has also been suggested to play music while the user is walking between points of interest.

6. CONCLUSIONS

In this paper, we have presented an experiment that compared three different ways of augmenting audio directions with visual directions to provide navigation guidance in mobile guides. Previous studies in the literature highlighted that maps are appreciated by users during navigation of an area because they clearly provide information about the position of the user. The results of our evaluation show that when combining a map with photographs that clearly show to the user the direction to follow during a tour or when removing the map completely and replacing it with a combination of directional arrows and photographs, users find their way more quickly than when using the map alone. This is likely due to the mental effort needed to switch between the egocentric perspective of the user and the geocentric perspective of the map (even when the map is forward-up). This result is also confirmed by some users' comments about the feeling of disorientation while using the map. Moreover, while both approaches exploiting photographs allowed users to obtain a similar performance, the solution combining photographs and map was highly preferred by users.

7. ACKNOWLEDGMENTS

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8. REFERENCES

[1] G. Abowd, C. Atkeson, J. Hong, S. Long, R. Kooper, and M. Pinkerton. Cyberguide: A mobile context-aware tour guide. *Wireless Networks*, 3(5):421–433, 1997.

[2] M. Agrawala and C. Stolte. Rendering effective route maps: improving usability through generalization. In *Proc. SIGGRAPH 2001*, pages 241–249, 2001.

[3] J. Baus, K. Cheverst, and C. Kray. A survey of map-based mobile guides. In *Map-based mobile services - Theories, Methods, and Implementations*, pages 197–216. Springer-Verlag, 2005.

[4] C. Borntraeger, K. Cheverst, N. Davies, A. Dix, A. Friday, and J. Seitz. Experiments with multi-modal interfaces in a context-aware city guide. In *Proc. Mobile HCI 2003*, pages 116–130. Springer-Verlag, 2003.

[5] S. Burigat and L. Chittaro. Location-aware Visualization of VRML Models in GPS-based Mobile Guides. In *Proc. Web3D 2005*, pages 57–64. ACM Press, 2005.

[6] G. Burnett. "Turn right at the traffic lights." The requirement for landmarks in vehicle navigation systems. *The Journal of Navigation*, 53:499–510, 2000.

[7] K. Cheverst, N. Davies, and K. Mitchell. Exploring context-aware information push. *Personal and Ubiquitous Computing*, 6:276–281, 2002.

[8] K. Cheverst, N. Davies, K. Mitchell, and A. Friday. Experiences of developing and deploying a context-aware tourist guide: The GUIDE project. In *Proc. MobiCom 2000*, pages 20–31. ACM Press, 2000.

[9] C. M. Chewar and D. S. McCrickard. Dynamic route descriptions: tradeoffs by usage goals and user characteristics. In *Proc. Smart Graphics 2002*, pages 71–78. ACM Press, 2002.

[10] D. Chincholle, M. Goldstein, M. Nyberg, and M. Erikson. Lost or found? A usability evaluation of a mobile navigation and location-based service. In *Proc. Mobile HCI 2002*, pages 211–224. Springer-Verlag, 2002.

[11] C. Ciavarella and F. Paternò. The design of a handheld, location-aware guide for indoor environments. *Personal and Ubiquitous Computing*, 8(2):82–91, 2004.

[12] J. Dillemuth. Cartography for Mobile GIS. In *GIScience 2004*, 2004.

[13] S. Fritz, R. Michel, H. Petrie, A. Raab, and T. Strothotte. MoBIC: user needs and preliminary design for a mobility aid for blind and elderly travellers. In *The European context for assistive technology*, pages 348–351. IOS Press, 1995.

[14] J. Goodman, S. Brewster, and P. Gray. How can we best use landmarks to support older people in navigation? *Behaviour & Information Technology*, 24(1):3–20, 2005.

[15] F. Hermann, G. Bieber, and A. Duesterhoeft. Egocentric maps on mobile devices. In *Proc. 4th*

International Workshop on Mobile Computing, IMC 2003, pages 32–37. IRB Verlag, 2003.

[16] F. Hermann and F. Heidmann. User requirement analysis and interface conception for a mobile, location-based fair guide. In *Proc. Mobile HCI 2002*, pages 388–392. Springer-Verlag, 2002.

[17] S. Holland, D. Morse, and H. Gedenryd. Audiogps: Spatial audio navigation in a minimal attention interface. *Personal and Ubiquitous Computing*, 6(4):253–259, 2002.

[18] J. Kjeldskov, C. Graham, S. Pedell, F. Vetere, S. Howard, S. Balbo, and J. Davies. Evaluating the usability of a mobile guide: The influence of location, participants and resources. *Behaviour & Information Technology*, 24(1):51–65, 2005.

[19] J. Kjeldskov, S. Howard, J. Murphy, J. Carrol, F. Vetere, and C. Graham. Designing TramMate - A context aware mobile system supporting use of public transportation. In *Proc. DUX 2003*. ACM Press, 2003.

[20] P. Klante, J. Krosche, and S. Boll. AccesSights - A multimodal location-aware mobile tourist information system. In *Proc. ICCHP2004*, pages 287–294. Springer-Verlag, 2004.

[21] J. Kolari and T. Virtanen. In the zone: Views through a context-aware mobile portal. In *Proc. Mobile HCI 2003 Workshop on HCI in Mobile Guides*, 2003.

[22] C. Kray, K. Laakso, C. Elting, and V. Coors. Presenting route instructions on mobile devices. In *Proc. IUI 2003*, pages 117–124. ACM Press, 2003.

[23] E. Kulju and E. Kaasinen. Route guidance using a 3D city model on a mobile device. In *Proc. Mobile HCI 2002 Workshop on Mobile Tourism Support*, 2002.

[24] K. Laakso, O. Gjesdal, and J. Sulebak. Tourist information and navigation support by using 3D maps displayed on mobile devices. In *Proc. Mobile HCI 2003 Workshop on HCI in Mobile Guides*, 2003.

[25] G. Pospischil, M. Umlauft, and E. Michlmayr. Designing LOL@, a mobile tourist guide for UMTS. In *Proc. Mobile HCI 2002*, pages 140–154. Springer-Verlag, 2002.

[26] Z. Pousman, G. Iachello, R. Fithian, J. Moghazy, and J. T. Stasko. Design iterations for a location-aware event planner. *Personal and Ubiquitous Computing*, 8(2):117–125, 2004.

[27] I. Rakkolainen and T. Vainio. A 3D city info for mobile users. *Computer & Graphics*, 25(4):619–625, 2001.

[28] F. Ricci, D. Cavada, and Q. Nguyen. Integrating travel planning and on-tour support in a case-based recommnder system. In *Proc. Mobile HCI 2002 Workshop on Mobile Tourism Systems*, 2002.

[29] C. Rocchi, O. Stock, and M. Zancanaro. Semantic-based multimedia representations for the museum experience. In *Proc. Mobile HCI 2003 Workshop on HCI in Mobile Guides*, 2003.

[30] T. Ross, A. May, and S. Thompson. The use of landmarks in pedestrian navigation instructions and the effects of context. In *Proc. Mobile HCI 2004*, pages 300–304. Springer-Verlag, 2004.

[31] C. Sas, M. O'Grady, and G. O'Hare. Electronic navigation - some design issues. In *Proc. Mobile HCI 2003*, pages 471–475. Springer-Verlag, 2003.

[32] B. Schmidt-Belz and F. Hermann. User validation of a nomadic exhibition guide. In *Proc. Mobile HCI 2004*, pages 86–97. Springer-Verlag, 2004.

[33] B. Schmidt-Belz and S. Poslad. User validation of a mobile tourism service. In *Proc. Mobile HCI 2003 Workshop on HCI in Mobile Guides*, 2003.

[34] M. Sester and C. Brenner. Continuous Generalization for Visualization on Small Mobile Devices. In *Proc. Spatial Data Handling 2004*, pages 469–480. Springer-Verlag, 2004.

[35] S. Winter and M. Tomko. Shifting the focus in mobile maps. In *Proc. UPIMap 2004*, pages 153–165, 2004.