Transparency in Mobile Navigation

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

Abstract
We investigated the usefulness transparency can play in increasing the display space of mobile devices in navigation scenarios. Two different systems that used transparency to display a map and image of a point of interest (POI) were compared to a control. Significant variations were identified in the strategies employed, with a strong user preference towards the transparency conditions. Significant variations in time or distance taken were not identified between conditions, although results indicate strong avenues for future investigation.

Keywords
mobile, navigation, transparency, way-finding

ACM Classification Keywords
H.5.2. Information Interfaces and Presentation: User Interfaces - *Interaction Styles*.

General Terms
Design, Human Factors.

Introduction
Whilst the widespread growth of mobile touch screen devices provides rich solutions for users in many mobile scenarios, significant limitations still remain, notably screen space. Whilst screen resolution has increased, the physical dimensions of mobile device displays remain largely unchanged. This is particularly an issue

Figure 1. An example POI that users had to find.

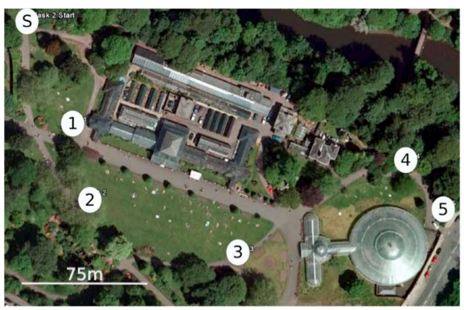

Figure 2. One of the routes used in the study, showing the start location and locations of the 5 POIs.

for mobile pedestrian navigation applications. Unlike most car navigation, pedestrian navigation is much more exploratory. Such navigation requires relating a map to the environment and, in many cases, to other aids, such as written instructions or photographs. Repeated studies have shown the importance of heterogeneous aids in location finding [1]. Brown and Laurier [2] identified that when trying to "home onto" a Point of Interest (POI) in the environment when the user was relatively close by, a map proved to be of little help, with a long time being spent trying to relate the map to the environment to locate the POI. Goodman *et al.* [3] found time taken in a route navigation task was reduced when participants had a mobile device with both a map and images of landmarks along the route, rather than just a paper map. Whilst the advantages of multiple aids is clear, when each is most appropriate and how best to switch between them on small mobile displays is not. Photographs, as indicated by Brown and Laurier [2], are likely more useful when the user is very close to the location he or she is trying to reach. Techniques such as using Augmented Reality (AR) are unlikely to be as useful when close to the POI, as even small accuracy errors in location sensing (such as GPS) will have a significant negative impact (e.g. indicating an incorrect direction to walk). In this paper we consider how switching between different aids might be accomplished, and the strategies users employ when "homing" onto unobtrusive POIs in the environment.

There are many ways to support switching between navigation aids [4], but we have chosen to look at how transparency – varying the opacity of multiple layers of content to allow each to be seen – can be applied. Relatively little work has been undertaken to investigate the use to which transparency can be put in a human computer interface, yet the technology to use transparency is built in to most desktop and mobile operating systems. The work that has been undertaken however, indicates transparency may be useful in mobile navigation scenarios. For example, parks and other pedestrian areas are often inaccurately represented in online map services. Schöning *et al*. [5] investigated allowing users to photograph "you are here" maps commonly found at the entrance. Users were able to overlay, adjust and stretch the photographs, aligning them with the same area on an online map, and allowing GPS and other location sensors to be used with the more detailed map. Transparency was used to aid users in aligning the online and photographed map.

Study Design

To investigate how transparency might be useful in navigation, we designed a study where participants had to complete navigation tasks to find and photograph five non-prominent POIs, such as named shrubs and trees (see Figure 2), in a local botanical gardens under three different counterbalanced conditions. Twelve participants (8 men, 4 women) aged 20-26 took part. None visited the park more than once a week. Three different routes of five landmarks each were randomly assigned to each condition for each participant. Participants used a custom Android application to view a map of the park showing the current location, as well as the location of the POI the user had to find. The application also supplied a photograph of the POI (see Figure 1). The way in which the user switched between the map and image varied by condition. Each route started at a fixed point in the park. At the start of each trial the participant was presented with the map

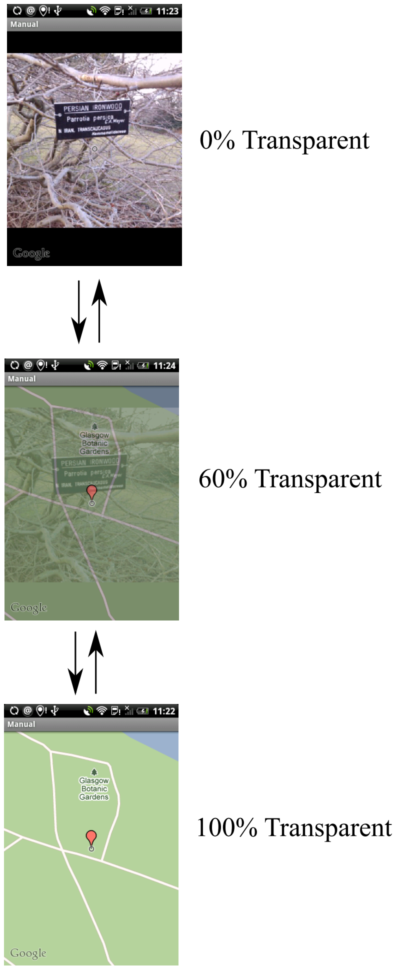

Figure 3. An example of the manual transparency condition, showing how image transparency changes as the user operates the scroll ball.

showing the POI to find. Participants were instructed to be efficient in finding the POI, but to stay on the paved paths. Shortcuts over the grass were not allowed. When the POI, as determined by the participant, had been found, he/she was instructed to photograph it using the in-built camera. When the photograph of the landmark had been taken the trial was ended. The participant was then walked to the POI, which served as the start location for the next trial. This continued until the condition ended.

Manual Transparency

In the manual transparency condition the photograph was presented on top of the map. By moving the scroll ball on the phone down and up the image became more or less transparent, allowing the map to be seen underneath. Moving the scroll ball upwards increased the opacity of the photograph, moving it downwards increased the transparency of the photograph (see Figure 3). Thus, it was possible to view both the map and photograph at the same time.

Automatic Transparency

The automatic condition was similar to the manual condition, except the transparency of the image was automatically modified according to the straight-line distance between the user and the POI. Using the built-in GPS on the device, the image was “faded in” as the user walked closer to the POI. Image opacity was increased linearly from fully transparent at a distance of 53m from the POI, to fully opaque as the user reached the POI. As the user gets closer we assumed that the map would be relatively less useful. In other scenarios, this assumption may well be reversed. We chose a distance of 53m based on informal testing, as it provided smooth fading in of the image.

Control Condition

In this condition the user accessed the image by tapping on the map marker representing the POI. The image was displayed on-screen at full opacity, hiding the map. The image was dismissed by tapping on it. This technique is similar to the way in which mobile devices currently provide details of POIs.

Results

In all conditions participants were very accurate in finding the landmarks (Mean accuracy > 95%). An ANOVA across all conditions failed to show significance ($F(1,11)=4.324$, $p=0.987$). As the study was undertaken outdoors, and to accommodate the differences in route length, we converted the distance and time taken for each trial into the proportion of optimal distance and optimal time for that trial.

Optimal trial distance was calculated as the shortest path length from the trial start location to the landmark. Proportion of optimal distance (POD) was calculated for each trial by dividing optimal distance by the distance the participant walked on that trial. Optimal time taken for each trial was calculated as the time taken to walk the optimal trial distance. This time was divided by the time taken for the participant to complete the trial to yield the proportion of optimal time (POT). An ANOVA on the POT ($F(1,11)=2.529$, $p=0.103$) and POD taken ($F(1,11)=1.258$, $p=0.304$) across all participants failed to show significance. However, ranking the conditions for each user from least to most optimal indicated that the manual and automatic conditions were more often optimal in time, but that the control condition was more often optimal in distance. The automatic condition was either most optimal or least optimal in distance (see Figure 4).

Whilst these results are not conclusive, they provide some indication that the transparency may be useful. Discussion with participants, and analysis of how users switched between the photograph and map in the control and manual conditions, offers some contextualization and avenues for future development.

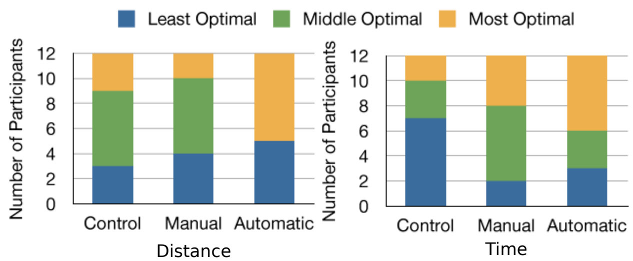

Figure 4. Objective ranked order of conditions from least to most optimal for each participant in terms of both distance (left) and time (right).

For both the manual and control conditions we logged the number of times the user switched between the map and image. For the control condition, this was the number of times the user activated or deactivated the image overlay. For the manual condition, this was the increase or decrease of the image transparency delineated by at least a 2 second gap, i.e. if two events occurred within 2 seconds they were treated as a single event. We also excluded events that lead to no change in the image transparency, such as when the user tried to increase opacity of a fully opaque. Figure 5 shows the mean number of such events across all participants. A Wilcoxon matched pairs test showed that participants performed significantly more events in the manual ($\overline{X}$ =19.75) than in the control ($\overline{X}$ =9.5) condition (T=3, n=12, $p<0.05$). The standard deviation in the manual condition was also substantively greater, indicating a much wider variation in the number of change events between participants. Detailed analysis of the logging data revealed that participants had employed different strategies for both the manual and control conditions.

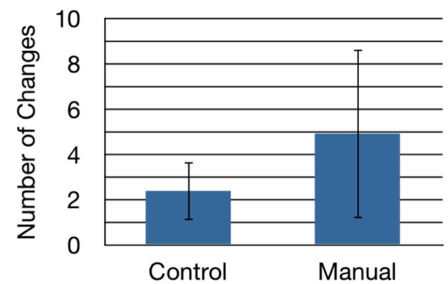

Figure 5. Mean number of transparency change events per trial for the control (2.3) and manual (4.9) conditions. Shown with standard deviations.

Manual Transparency Condition Strategies
Based on the log files, two strategies for the manual transparency condition were observed. It may be expected that the most suitable strategy would be to set the opacity of the image and map to be the same, so that both could be seen equally. However only one participant adopted this strategy. The other 11 used a "bouncing" strategy (see Figure 6).

Participants regularly scrolled the image transparency up and down, fading the image in and then out. As each trial progressed, subsequent increases and decreases tended to move the mean opacity of the image higher, increasing the peak value over the course of the trial. However, the number of "bounces" during the trial, as well as the rate and amount of image transparency change, varied significantly both between and within participants.

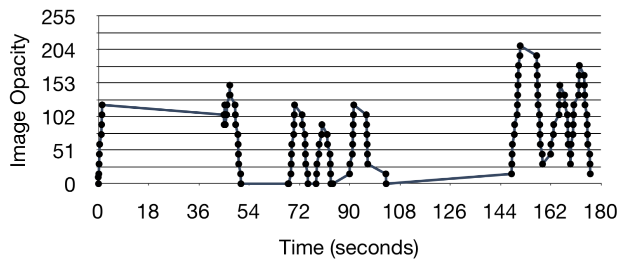

Figure 6. Graph illustrating the "bouncing" technique used by participants in the manual condition.

Control Condition Strategies

Participants moved between the image and map fewer times than in the manual condition. There was also less variance in the strategies employed. The image was viewed and dismissed only two or three times per trial. Commonly, this was once at the start of the trial and then one or more times towards the end of the trial. The image was left on-screen for between 3 and 10 seconds before being dismissed. Two participants had a more even dispersal of switches, but the amount of time each image stayed on-screen was the same. Given the observations during the study, we believe that there was a higher cost to activating the image as participants tended to stop walking, as well as losing context in the map as the photograph obscured it. This meant that participants only used the image when they felt it was strictly necessary. This may be a reason why the control condition was more often optimal in distance but less often optimal in time.

Qualitative Feedback

The strategies identified in using the transparency were confirmed by post experiment interviews with participants. Ten of the participants expressed a preference for the manual condition, with two expressing a preference for the automatic condition. No participants expressed a preference for the control condition. The reasons for this were largely based on the ability to tailor the interface to suit the particular circumstances the user was faced with, allowing easier comparison with the map, image and environment. As one participant noted: *"The manual (condition) was quite good, in that you could have both at once. You could decide how clear to make it (the image) and you could easily move between the two"*. Another described the manual condition as: *"smoother than the control condition, it's easier"*. The control condition was problematic as the image obscured the map: *"...switching back and forth didn't really work for me and it covered the map and I didn't really want that".* The two participants who expressed a preference for the automatic condition felt that it was better as explicit interaction with the device was not required: *"it was easier to use and smarter over how much fade you should have than I was ...... The control (condition), it got in the way, cause you had to constantly stop, look, tap. Well not stop, but it detracts from your focus. Same with the manual (condition)".* However, the other participants expressed strong views against the automatic system. Partly these were due to GPS inaccuracy issues or cases where the determined position lagged behind the user: *"I didn't like the automatic condition because the closer you got to the thing, the picture went right over the map, so if the GPS wasn't updating very quickly, you didn't know where you were".* The major issue was the lack of control participants had in being able to move between the image and map. One participant noted that the automatic condition caused: *"lack of control when you actually need it. Sometimes if the map is very complicated, or whatever, it's exceptional to the normal* *rules then you need control".* These limitations were also noted by the two participants who had rated it as their preferred condition. One suggested that a combination of the manual condition and the automatic condition - where transparency was automatically varied, but could be overridden - would be a better option: *"you'd be able to flick it to your chosen setting and then it would fade back to whatever its choice of setting was after about 10 seconds"*.

Discussion

Transparency is not a new concept, but it is clear that there is a role for it in a user interface for pedestrian navigation. The transparency made the ability to change less costly as the user did not loose context in the map when looking at the image. We had expected the automatic transparency condition to be more popular, as it was designed to guide the user and present the information more relevantly. However, as exhibited by the "bouncing" strategy in the manual condition, participants were keen to tailor their interaction to the task at hand. Although there is some indication (see Figure 4) that the transparency conditions may be more optimal, the effect was not significant in either time or distance travelled. Our future work will therefore seek to improve the transparency conditions by integrating the automatic and manual conditions, automatically setting transparency but allowing users to override if desired. We also intend to incorporate other transparency techniques[6] to more intelligently combine the image and map as well as consider other data types such as notes. We believe that incorporating these improvements will allow us to significantly improve the effectiveness of heterogeneous navigation aids on mobile devices and will allow users to connect with their environment more effectively.

Acknowledgements

Supported by EU FP7 Project No.224675 "Haptimap"

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