An Empirical Study of Textual and Graphical Travel Itinerary Visualization using Mobile Phones

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Abstract

Mobile phones can be used to access personal and public information. Although most of these types of information are in textual form, an increasing number of service providers are also offering access to graphical information, particularly to WAP-enabled mobile phones. This paper describes an empirical study of user access to personal travel itinerary information in both textual and graphical form. The aim of this study was to compare the effectiveness of graphical and textual visualizations in providing users with easy access to different kinds of information on their travel itinerary. The study indicates that although the graphical visualization was generally as effective as textual visualization, the users preferred textual visualization to a graphical one, possibly because they were more familiar with textual itineraries.

Keywords: Mobile computing, information visualisation, WAP.

1 Introduction

Small handheld computing and communication devices, particularly mobile phones, have become common every day objects around the world. The usage of such devices has also radically changed from traditional personal diary/organizer type applications, to include many other activities commonly performed through desktop computers. It is in fact not unreasonable to assume that small handheld devices may one day become the more preferred computing tools over standard desktop computers. Many predict that for instance access to the Web through wireless devices will overtake worldwide wired access within a few years (Marcus, 2001).

Perhaps the main reason for the enormous popularity of mobile devices is their small physical size and portability. This portability, however, brings with it limitations in terms of input and output capabilities, making the interface design of such devices very challenging. Although over the past two decades human-computer interaction standards have been developed and tested, allowing a marked improvement in usability of desktop computers, such standards cannot always be applied to design applications for mobile devices. Designers of interfaces for handheld devices have come to realize that novel user interface design for small screens is far from straightforward adaptation of techniques developed for traditional large screens to their smaller counterparts (Holmquist 1999).

One major aspect of interface design of mobile devices that has received relatively little attention is information visualization (Marcus 2001). For instance, the latest mobile phones often have a multitude of functions, many of which are hardly ever used, often because these functions are hidden within endless menu options (Holmquist 1999).

It is therefore obvious that designers of new applications and services for mobile devices not only need to consider carefully how information is visualized and presented on small screens, but also test such visualizations with users to make sure that these visualizations are effective in conveying desired information to the users.

This paper discusses an empirical study which was undertaken to compare textual and graphical visualizations of travel itinerary information, developed for WAP-enabled mobile phones. The paper briefly describes the rationale for development of a prototype system for accessing personal travel itinerary information using mobile phones, followed by a discussion of its main textual and graphical visualizations. The prototype system itself, which is called MATI, has been discussed more fully elsewhere (Masoodian, and Lane 2002, Masoodian, and Lane 2001).

2 Graphical Travel Itinerary Visualization

Conventional paper-based travel itineraries are often in a tabular form, listing travel events in a chronological order of time and date. These tabular travel itineraries are generally less than satisfactory to carry, use, or change and update especially during a long travel which may include several flights, transport or accommodation bookings and other travel activities.

A problem with conventional travel itineraries is that they often don't provide an overview of the relationship between various events of a trip. The only relationship which can be viewed in these types of itinerary is that various events follow one another sequentially in time. For example, for a particular trip it might be easy to check if London is going to be visited before Los Angeles or not, but it may be a bit more difficult, or nearly impossible, to find out the arrival time in London based on the local time of Los Angeles after a long flight from Los Angeles to London.

As part of a Collaborative Information Gathering (CIG) software, a graphical visualization tool has been developed to assist travel agents and their clients with the process of collaborative creation and viewing of travel itineraries remotely over the Internet (Apperley, Fletcher, and Rogers 2000, Masoodian, and Lane 2002)

Figure 1 shows an example roundtrip between Perth and London, with stops in Sydney and Los Angeles. The vertical axis is in time-zone units, showing the time difference between various locations, as well as the international dateline when necessary. The vertical axis also shows the names of the cities which are either destinations or transit points along the way.

The horizontal axis, on the other hand, shows the normal progression of time at a particular location. From this axis it is possible to see for instance how long a flight has taken or how long a hotel stay is. When a travel crosses the international dateline, the difference between days on different hemispheres is shown along the top and bottom lines of the visualization.

Using these two different time scales it is possible to compare the time of various events across different time-zones. A horizontal black line depicts a stay event in a location, while the upward and downward lines show travel eastward, or westward respectively. The dark and light shaded stripes show the 12-hour night and day periods while midnights and middays are marked with a dark grey or a white diagonal line.

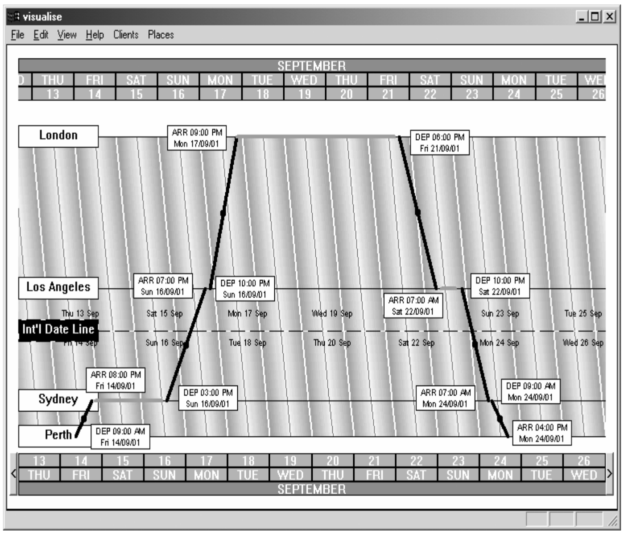

Figure 1: Travel itinerary visualization showing a return trip between Perth, Australia and London, UK

3 Mobile Access to Travel Itinerary

Although the CIG visualization tool has been designed to solve problems associated with tabular travel itineraries (Thomson, and Apperley 1999) its use remains limited due to the fact that it requires a computer with conventional large display, and access to the Internet.

A prototype system called MATI (Mobile Access to Travel Itinerary) was therefore developed to provide access to the CIG system using a WAP-enabled mobile phone (Masoodian, and Lane 2002, Masoodian, and Lane 2001). Wireless Application Protocol or WAP (Varshney, and Vetter 2000) is one of the more widely accepted standards for providing Internet-based services to most handheld devices including mobile phones and PDAs.

Although WAP suffers from a number of limitations, such as the high usage cost, it was chosen as the basis for MATI mainly because it allows easy access to documents written in WML (Wireless Mark-up Language) and WBMP (Wireless BitMap) images over the Internet; providing simple, yet effective, means of delivering interactive documents and monochrome graphics to mobile devices.

The graphical travel itinerary visualization of CIG is clearly far too complex to be displayed effectively on the small display of a typical mobile phone. It was therefore necessary to modify the visualization by making it less complex, while at the same time keeping its most beneficial features (Masoodian, and Lane 2002). MATI is designed to provide access to a simplified version of the CIG visualization. MATI allows users to access travel itinerary information in two different modes, textual and graphical.

3.1 Textual View

Textual view of the travel itinerary information is the simplest kind of view that MATI provides. Figure 2 shows several sample pages accessed via MATI. All of these pages relate to the example CIG itinerary visualization shown in Figure 1. As can be seen from Figure 2, in textual view MATI allows the users to access the list of all the destinations of an itinerary (2a), from which the users can select a particular destination (2b) to find out information related to that destination (2c), for instance all the hotel bookings related to that city (2d) or the details of a particular hotel (2e).

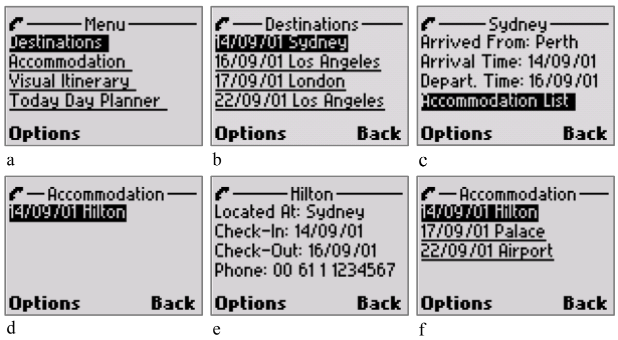

Figure 2: a) the main menu of MATI
b) destinations list of the whole itinerary
c) information relating to a particular destination
d) accommodation list for a particular destination
e) information relating to a particular hotel
f) accommodation list of the whole itinerary

MATI supports user access to some information via different paths. For example, one can access information about a hotel booking either by following the path described above (2a, 2b, 2c, 2d, 2f) or directly via the list of all the hotels (2a, 2f, 2e).

Furthermore, as the textual view provides more details about all the events of an itinerary, it can also be accessed through the graphical view which aims to support an overview of the itinerary rather than its specifics.

3.2 Graphical View

Figure 3 shows several pages from the graphical visualization of MATI. The users of MATI can select different levels of zoom for viewing an itinerary (3a). It is possible to either get an overview of the entire itinerary (3b), or a specific time period (3c) from which the user can access previous or next consecutive time periods (3d, 3e). The users can also jump directly to a weekly (3f) or monthly view.

It is important to note that the amount of information MATI provides about different events in the graphical view changes based on the level of zooming selected by the user. For instance, when a period of time selected by the user is sufficiently small enough, MATI shows the hours of the day during which different events are going to take place using a simple clock-face system in 3-hour day and night slots (3f). On the other hand, if the selected time period is large, only the dates of the days in which events occur are shown (3b).

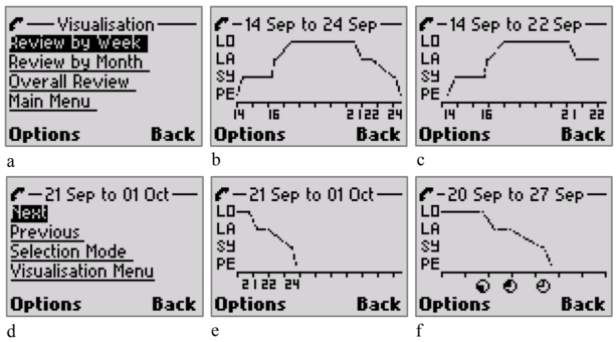

Figure 3: a) menu for different levels of viewing
b) overview of the whole itinerary
c) the first 9 day period of the itinerary
d) menu for selecting the next or previous period
e) the next 9 day period of the itinerary
f) a weekly view of the itinerary

If the users require further information about the itinerary events they can access these via the textual view. One way of accessing textual information has already been demonstrated (Figure 2). Another interesting way of accessing textual information is through the graphical selection mode.

Figure 4 shows how the users can change from graphical navigation mode to graphical selection mode (4a), allowing them to step through different events (4b, 4c, 4d) and select to view information relating to the current event (4e, 4f). It is also possible to switch back from selection mode to navigation mode (4c or 4e).

Another way of selecting events for accessing more detailed information is by using the day planner. This method allows the users to rapidly move between different weeks of an itinerary, followed by choosing the relevant day, and subsequently selecting the desired event. MATI can also utilize information about the current date and time to filter irrelevant itinerary events. For example, users can activate the time awareness feature of MATI so that the system would only give the itinerary events which are going to happen in the future, ignoring all the past events.

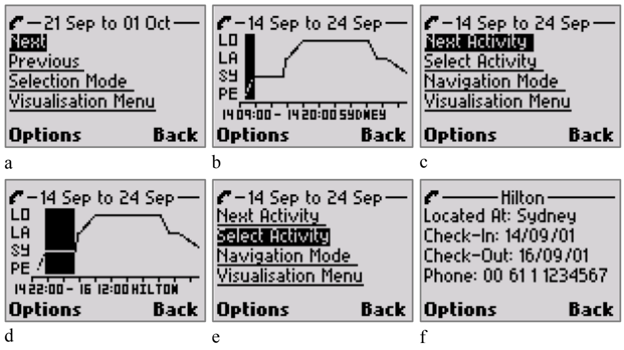

Figure 4: a) switching from navigation to selection
b) the current travel activity
c) menu for selecting the next or previous activity
d) the next activity
e) selecting an activity for more information
f) details of the current activity

4 Empirical Study

An empirical study was conducted to compare the effectiveness of textual and graphical visualizations of MATI in conveying different kinds of travel itinerary information to the users. The experiment aimed at finding the answers to the following two questions:

- How effective is the graphical visualization in providing the users with an overview of the itinerary?
- How effective is the graphical visualization in providing the users with easy access to details of travel events?

4.1 Methodology

As the aim of this experiment was to compare two different visualizations of MATI rather than its overall usability in real-life settings, it was decided that the experiment could be conducted reasonably well using a PC-based emulator instead of using a much more costly WAP-enabled mobile phone.

The participants interacted with MATI using the Yospace SmartPhone WAP Emulator (2002) emulating the Nokia™ 7110 WAP capable mobile phone (Väänänen-Vainio-Mattila, and Ruuska 2000). Once again, the choice of this particular emulator and phone model was considered not to be important in the context of this study. The subjects used a standard personal computer and interacted with the software through selected keyboard keys, to maintain a degree of similarity of interaction with a real phone. The emulator screen size was set to simulate the users holding the device approximately 15cm from their face.

Participants were asked to find answers to a set of questions within each visualization environment. The study used *within-subject* design where each participant responded to a different set of questions within each environment. The design was counter balanced so that any transfer of learning did not influence the results. Two similar sets of questions were used, each based on two similar travel itineraries. These sets of questions, referred to as task 1 and 2, were randomized across the two environments (see Table 1). Each ordering of the tasks and environments were replicated 6 times, requiring 12 participants in total.

Participant	Textual Visualization	Graphical Visualization
1	task 1	task 2
2	task 2	task 1

Table 1: Within-subject design of the experiment

Participants were required to fill out a background questionnaire at the beginning of the session. General background information such as age and occupation were recorded along with users' previous travel and mobile device experience. The participants performed their tasks in each of the environments consecutively during a single session. Before starting their task in each of the environments the subjects read a tutorial, which provided necessary information about that particular visualization.

4.2 Subjects

Subjects were mainly composed of local university students, and they each received a book voucher for their participation in the experiment. Most of the subjects had travel experience abroad, and had used mobile phones in the past. Very few of them had however any experience of a WAP application. Table 2 gives a summary of the profile of the subjects.

Average Age	21 years	
Gender	male (58%)	female (42%)
Occupation	students (92%)	administration (8%)
International Travel Experience	yes (75%)	no (25%)
Mobile Phone Experience	yes (67%)	no (33%)
WAP Experience	yes (8%)	no (92%)

Table 2: Profile of the subjects

4.3 Tasks

Two sets of questions (tasks) were selected for this experiment. Each task contained 8 questions, with each question requiring similar user skills to answer correctly. The tasks were based on two fictional travel itineraries. Each task contained activities that either required simple interaction with the interface or alternatively required some interpretation of the information displayed on the screen. Table 3 gives a summary of the objectives of each of the task questions, while Table 4 shows the questions for Task 1. After each question the subjects were asked to explain the reason for their answer, and describe how difficult the question had been to answer on a three-point scale: obvious, had to think about, and difficult.

After the completion of each task the subjects responded to a questionnaire about the visualization environment in which they had just worked. Table 5 gives a summary of the relevant parts of this questionnaire.

The users also completed a summary questionnaire at the end of the session which compared the two visualization environments. This questionnaire compared the two visualizations in terms of the ease with which the subjects were able to understand the overview of the itinerary, find the length of flights, find the length of stay events, find the destination city at a particular point in time, as well as their overall preference for any of the visualizations.

Questions	
1.	Determine arrival time at a location
2.	Determine location at a particular instant in the itinerary
3.	Determine flight length taking into account time zone changes
4.	Compare travel duration lengths
5.	Determine length of a stay event
6.	Make decision based on multiple itinerary data
7.	Determine specific accommodation details for a particular
8.	Make decision based on multiple itinerary data

Table 3: Summary of the objectives of the task questions

Questions	
1.	What day, date and time do you first arrive in Frankfurt (Germany)?
2.	Which location do you leave on Monday the 24th of December?
3.	How long will it take for you to fly from Los Angeles (USA) to Frankfurt (Germany) at the start of your trip?
4.	Of the last three flights taken during the itinerary which is the longest?
5.	How many days will you be in Frankfurt (Germany) in your first stay beginning on the 13th?
6.	You want to go to a basketball game in Los Angeles on the 28th between connecting flights. The game begins at 6:00p.m. Assume the game and all travel required will take 6 hours in total and ignore all complications in going to the game and catching the flight such as checking in at the airport early and going through airport security. Can you go to the game?
7.	On the 16th you are staying at a hotel, what is its name and phone number?
8.	When you fly from London to Germany on the 24th, do you have enough time to catch a movie that is 2 hours in length and is playing at the airport movie theatre in London, starting at 7:00p.m?

Table 4: Summary of the questions of Task 1

Questions	
1.	Was there enough information represented in the interface?
2.	Did you find the overall schedule obvious from the visualization?
3.	Did you find the navigation easy?
4.	Did you find the naming and labelling within the interface clear?

Table 5: Summary of the comparison questionnaire

4.4 Data Collection

The experiment was conducted in a usability laboratory, where video recordings of the sessions were made using digital video equipment. Video feeds from (i) a scan converter displaying the mobile phone emulation software on the computer screen, (ii) a camera pointing at the subject's face to capture facial expressions, (iii) and a camera pointing at the subject's workbook were combined into a single tiled video image and recorded onto tape. The subject's workbook consisted of the visualization tutorials, task question sheets, and the questionnaires. It was decided to make video recordings of the subjects' interaction with their workbook so that a number of data, such as the time taken to answer each question, could be measured based on when the subjects finished with a particular question and started on the next.

The data collected during this study consisted of the following range of objective and subjective data:

- objective: time taken to complete the individual questions, the number of links needed to be followed to complete a task (refereed to here as clicks), and percentage of questions completed correctly.
- subjective: degree of user satisfaction, user comments and suggestions.

5 Results

5.1 Objective Data

The objective data collected during this experiment were analysed on a participant basis, as well as a question basis. The results of both these analyses are discussed below.

5.1.1 Means Analysis by Participant

Table 6 shows the result of the means analysis by participant. The data values for each task question completed by the participant were averaged and grouped by visualization style. The raw means of time, accuracy and clicks for accessing information using textual visualization methods were better for almost every participant than those achieved by participants using graphical visualization methods.

Table 7 summarizes this result by finding the mean participant metrics per question. The p-value calculated in Table 7 is with a null hypothesis that population means for each visualization environment are equal. The small p-values of the time and accuracy support that differences observed between the means are significant. However the difference between clicks required to complete each task question is statistically insignificant.

5.1.2 Means Analysis by Question

Table 8 shows the result of the means analysis by question. Each mean value recorded for each task question was calculated with the task questions grouped by visualization environments. For the majority of questions it seems that performance in textual visualization is better than that of graphical visualization; in reality though these differences are not statistically significant (see Table 9). The p-value for the sample of mean accuracy percentages for each question was calculated at 0.18, which also implies that any difference in accuracy is statistically insignificant.

Participant	Textual Visualization			Graphical Visualization		
	Time (s)	Accuracy	Clicks	Time (s)	Accuracy	Clicks
1	106.4	100%	20.6	83.8	100%	11.1
2	100.6	86%	9.5	77.0	57%	7.9
3	67.1	88%	6.0	123.4	71%	9.1
4	102.4	75%	11.8	140.4	38%	12.9
5	68.1	88%	7.9	61.6	75%	4.8
6	126.8	50%	10.3	129.0	88%	10.9
7	108.0	88%	10.4	181.1	50%	9.6
8	96.1	100%	5.6	92.6	100%	12.9
9	42.8	63%	4.1	90.0	25%	13.0
10	47.5	100%	5.3	67.4	75%	7.1
11	72.6	75%	5.5	167.3	25%	9.8
12	86.0	86%	9.6	142.8	50%	53.8
Averages	**85.4**	**83%**	**8.9**	**113.0**	**63%**	**13.6**

Table 6: Means analysis by participant

	Textual Visualization	Graphical Visualization	p-value
Average Time	85.4 seconds	113.0 seconds	0.056
Accuracy	83%	63%	0.031
Clicks	8.9	13.6	0.246

Table 7: Summary of means analysis by participant

Question	Textual Visualization			Graphical Visualization		
	Time (s)	Accuracy	Clicks	Time (s)	Accuracy	Clicks
1	56.33	83%	7.00	87.92	25%	6.25
2	65.25	100%	6.17	72.75	91%	7.08
3	165.30	83%	11.91	196.42	25%	26.17
4	108.09	80%	9.64	139.45	80%	13.27
5	71.33	83%	4.33	57.45	91%	7.27
6	101.08	58%	14.42	123.27	73%	8.45
7	70.27	83%	9.91	99.27	90%	17.20
8	86.91	83%	8.50	92.89	63%	18.00

Table 8: Means analysis by question

Question	p-value	
	Time (s)	Clicks
1	0.20	0.98
2	0.41	0.51
3	0.36	0.86
4	0.48	0.58
5	0.99	0.16
6	0.71	0.43
7	0.45	0.85
8	0.85	0.35

Table 9: Summary of means analysis by question

5.2 Subjective Measures

5.2.1 Participants' Perception of the Difficulty of Questions

As mentioned earlier, after each task question the subjects were asked to rate the difficulty of the question on a scale of: obvious, had to think about, and difficult. The results of the analysis of the subjects' response to the rating of the questions in both visualization environments are shown in Table 10. The results suggest that questions answered using the textual visualization were perceived as being marginally easier than those answered in the graphical environment.

	Textual Visualization	Graphical Visualization
Obvious	59%	45%
Had to Think	27%	39%
Difficult	14%	18%

Table 10: Subjects' perception of the difficulty of all the questions in two environments

As would be expected, the users' perception of the difficulty of each question match the level of their performance in relation to the questions. This means that the questions which participants found most difficult, such as Question 3, were performed badly in terms of variables such as accuracy and time elapsed. Divergence between user perceptions of difficulty for questions performed in each visualization style occurred where the performance metrics also diverged. Differences in perception between visualization styles, seen in Table 11, seem to follow the pattern that was seen earlier in performance metrics. Once again, questions that required specific details were easier to answer in the textual visualization than the graphical.

	Textual Visualization			Graphical Visualization		
Question	Obvious	Had to Think	Difficult	Obvious	Had to Think	Difficult
1	83%	17%	0%	25%	58%	17%
2	58%	42%	0%	50%	33%	17%
3	25%	50%	25%	27%	45%	27%
4	45%	18%	36%	45%	18%	36%
5	55%	36%	9%	75%	25%	0%
6	27%	36%	36%	30%	60%	10%
7	83%	17%	0%	73%	18%	9%
8	64%	27%	9%	60%	30%	10%

Table 11: Subjects' perception of the difficulty of individual questions in two environments

5.2.2 Participants' Responses to Comparison Questionnaires

After each task was completed participants completed a questionnaire about the visualization style they had just used. Table 12 presents a summary of their responses to the questionnaire completed after using the textual visualization. The results indicate that the subjects were satisfied with the amount of information available within the interface. It is also clear that labels used within the visualization, and general interface navigation were easy to understand.

Table 13 presents the results of the equivalent questionnaire produced for the graphical visualization. Participants were unanimous that there was sufficient information in the graphical visualization. Users considered it harder to deal with time differences and marginally harder to determine the overall itinerary than with the textual visualization. Participants agreed that labeling and navigation was still fairly simple but the distribution of responses was shifted away from strong agreement relative to the response the textual visualization received.

	There was	There wasn't
Was there enough information presented?	83%	17%

	Obvious	Had to think	Difficult
The overall itinerary was…	67%	33%	0%
Time differences within the itinerary were…	36%	27%	36%

	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
Interface Labels were not confusing	0%	8%	17%	50%	25%
Tutorial covered all features	0%	9%	18%	55%	18%
Navigation was easy	0%	8%	17%	58%	17%

Table 12: Summary of the comparison questionnaire for textual visualization

	There was	There wasn't
Was there enough information presented?	100%	0%

	Obvious	Had to think	Difficult
The overall itinerary was…	33%	50%	17%
Time differences within the itinerary were…	8%	50%	42%

	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
Interface Labels were not confusing	0%	25%	25%	25%	25%
Tutorial covered all features	0%	8%	33%	42%	17%
Navigation was easy	0%	8%	33%	42%	17%

Table 13: Summary of the comparison questionnaire for graphical visualization

5.2.3 Participants' Responses to Summary Questionnaires

Participants completed the summary questionnaire at the end of their session. Their response to this questionnaire is summarized in Table 14. As this summary shows the subjects felt that the overview of the itineraries and the length of flights were easier to be determined within the textual visualization, while accommodation lengths and general whereabouts at a specific point in the itinerary were easier to be determined from the graphical visualization. Overall participants liked the textual visualization more than the graphical visualization.

	Textual	Graphical	Equal	Neither
Overall Itinerary easiest to determine in…	58%	33%	8%	0%
Length of Accommodation easiest to determine in	17%	50%	33%	0%
Length of Flight easiest to determine in…	50%	40%	10%	0%
Easiest to determine whereabouts in…	36%	45%	36%	0%
I prefer…	67%	25%	8%	0%

Table 14: Results of the summary questionnaire

6 Discussion

The results of this study clearly indicate that although the graphical visualization was reasonably effective in providing users with overview of some aspect of their travel itinerary, as well as giving them sufficient access to necessary details of events, overall it was less effective than the textual visualization.

While the differences of time and accuracy were of statistical significance, the metrics of the graphical visualization were skewed by the extreme difficultly some participants had on a couple of questions. For instance the large number of clicks a participant had during one task question under the graphical visualization shifted the mean clicks per question for every participant from 10.6 to 13.5 (a 27% increase). The difference of metrics between visualization styles was reduced when analysis was carried out on a question basis. This caused extreme individual results to only influence the metric for a single question and not the entire set. Under this arrangement the differences of the metrics of time, clicks and accuracy were found to be insignificant for every task question.

The pattern of results observed in the performance metrics continues into the results from the questionnaires on participant perceptions. Participants found the graphical visualization more difficult to use. This is no great surprise given the familiarity users generally would have with the textual visualization metaphors especially relative to those of the graphical visualization. As a consequence the users preferred the textual to the graphical visualization. It was anticipated that the graphical visualization would be easier with questions requiring an overall understanding of the itinerary but this only appeared to be the case in relation to accommodation duration.

However, when these results are considered within the context of the current study, they might actually suggest that the graphical visualization would perform much more effectively in real-life situations. This claim is based on the following factors:

- in this study the graphical visualization was used in isolation from the textual visualization. In reality though, the graphical visualization is an extension to the textual visualization, and therefore would generally be used as a mechanism for locating and accessing textual information within the itinerary which provides more accurate details of events.
- in real-life situations it is expected that people will use the mobile system in conjunction with the PC-based CIG graphical visualization. People would use CIG system for planning their trip, which would give them a better understanding of the graphical notation, as well as, providing them with the initial overview of the itinerary in graphical form. This means that when they use MATI for accessing information during their trip they would be familiar with the overview of their itinerary.

7 Conclusions

This paper has described MATI, which has been designed to allow mobile phone access to personal travel itinerary information. An empirical experiment which has subsequently been conducted to investigate the effectiveness of the graphical and textual visualizations of MATI, has shown that the textual style generally outperforms the graphical style when there are used on their own.

It is expected that when both of these visualizations of MATI are used together in real-world settings, they will provide the users with effective access to their itinerary information. This form of access would certainly be a major improvement over the use of conventional paper-based tabular itineraries.

This research has also demonstrated the limitations of the WAP-based mobile phones for accessing graphical information. Currently a more advanced system is being developed for PDA type devices which would improve the quality of access to travel itinerary information, as well as providing the users with the possibility of modifying their itinerary during the course of their travel.

8 Acknowledgments

The research described in this paper was partly funded by the Foundation for Research, Science and Technology, through Public Good Science Fund grant number UOW808. The authors would also like to acknowledge the contributions of other members of the CIG research team, in particular Kirsten Thomson who has helped with the design of the empirical study.

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