Evaluation of User Interface Satisfaction of Mobile Maps for Touch Screen Interfaces

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***Abstract*—User interfaces of mobile maps on mobile and tablet devices with a touch screen interfaces is evaluated in this study. A four-way factorial experiment compares the user interface satisfaction for two mobile touch devices (iPad/iPhone), two map types (Electronic Map/Mixed Map), two keyword searches (Landmark/District), and Chinese input methods (Hand-written/Phonetic notation). The experiment used forty-eight participants, each of whom was assigned three types of environmental spatial tasks: find targets, identify cardinal directions, and identify approximate distances. The individual differences between gender, the possession of a sense of direction and route knowledge on user's satisfaction were also examined. The results of the study verify that both the reliability and confirmative factor analysis model of the questionnaire for user interface satisfaction are good enough. In addition, the two-factor interactions and the main effects: Type, Keyword, and Input significantly affect the degree of user satisfaction.**

Keywords-User Interface Satisfaction; Mobile Map; Mobile Spatial Interaction; Touch Screen; Sense of Direction.

I. INTRODUCTION

The functionality of mobile maps has been greatly increased by the use of new interactivity technology. Maps can be zoomed in and out and rotated without affecting the ratio of the display and can be easily combined with satellite images, aerial photographs and other sources of information to improve the user's understanding of the geographic database. The use of mobile maps is becoming popular with most mobile users; especially with the availability of free Google Maps for mobile phones. Google Maps for Mobile (GMM) claim that paper maps are obsolete. It offers street maps, a route planner for traveling by foot, car, or public transport and an urban business locator, for numerous countries around the world. Mobile phones can be used to search for local businesses, and then to obtain direction [3].

Touch screen tablet PC's have become increasingly popular, since Apple launched the iPad device. They enable direct interaction with what is displayed on the screen, rather than indirectly with a mouse or touchpad. "*It looks like a giant iPhone*," is the first thing users say when asked to test an iPad. However, from the perspective of interactive design, an iPad User Interface (UI) is more than a scaled-up iPhone UI [1]. The recent boom of popularity of mobile and tablet devices such as the iPhone and iPad open up a new world of opportunity for mobile global positioning system (GIS) applications [13].

Literature concerning map-reading has shown that using a map is not an easy task for children, or even for adults [10]. Route-finding aids are important for finding routes in unfamiliar territory, in order to learn, about the surrounding environment. In particular, due to the advent of advanced information technologies, devices equipped with GPS receivers are becoming valuable tools for providing positional information [15]. With respect to navigational aids, studies such as in [7] have examined the effectiveness of GPS-based mobile navigation systems in comparison to paper maps and direct experience of routes. Their results show that GPS users travel longer distances and make more stops during the walk than map users and participants with direct experience of a route.

Various presentation formats for spatial information have been developed, including verbal navigational directions, static maps, interactive maps, 3-D visualizations, animations and virtual environments [12]. Dillemuth [2] showed that a faster speed of travel and fewer navigation errors occur with a generalized map than with an aerial photograph. Some people can readily find their way back to a starting point along a route they have only experienced once, whilst others can only do this with considerable difficulty. There are large differences in individuals' environmental spatial abilities [4, 8]. This individual difference between people is referred to as the sense of direction (SOD). Self-reported assessments of SOD have been found to provide quite accurate and objective measures of these abilities [5]. Participants with a good SOD (GSD) showed much better performance on route learning than those with a poor SOD (PSD). In addition, concerning gender differences in spatial cognition, it was suggested that males were superior to females in spatial information processing. Males preferred and used much better Euclidean spatial cues such as direction and distance, while females were likely to memorize landmark cues [9].

Usability is the extent to which a computer system enables users, in a given context of use, to achieve specified goals effectively and efficiently while promoting a feeling of satisfaction. Understanding what users expect to find and want to find, as well as what they typically use GMM for, can help the mapping service designers to provide a user-centered design. Moreover, understanding the needs of GMM will help improve the user experience and increase the service's usability. The effects of four designing factors

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including Size, Type, Direction Key, and Zoom function has been examined in [11]. The results indicate that participants with a better SOD would have the faster response time and would lower overall workload for target task. However, mobile maps differ from paper maps in that it provides a facilitation of spatial search. Keyword search using landmark or district and Chinese input methods using traditional Chinese hand-written input or traditional Chinese phonetic notation keyboard input for GMM spatial queries are concentrated on this research.

In this paper we discuss user interface satisfaction (UIS) that arose in using GMM on mobile devices with a touch screen interface such as the iPhone and iPad. This study differs from previous studies [7,10,11,12,15] in that it concentrates on the effects of keyword search and Chinese input methods that affect UIS. We first present our experimental design, including a description of the interfaces evaluated. Four design factors (Interface, Type, Keyword, Input) and two background factors (SOD and route knowledge) on UIS were examined. It helps Apps designers to provide an optimal user-centered interface for GMM. We follow with a description of our research methodology, define a classification scheme of SOD used in our analysis, and then present the results. The paper concludes with a discussion of design implications followed by future work.

II. METHOD

A. Participants

Forty-eight undergraduate, graduate students, teaching assistants and staff (24 females and 24 males) voluntarily participated in the experiment. Their ages ranged from 20.7 to 39.7 years old, with a mean of 23.7 years and standard deviation of 3.5 years. Nine out of Forty-eight participants had experience in using mobile E-maps other than GMM, before the experiment. They all had normal vision or corrected vision of at least 0.8 and no color-blindness. Participants were required to abstain from PC use for one hour before the formal experiment.

B. Materials and Apparatus

The experiment used an iPad with a 9.7-inches multi-touch LCD display (1024×768 pixels) as a representative tablet PC and an iPhone with a 3.5-inch multi-touch retina display (960×640 pixels). An Optical Vision Tester was used to measure vision acuity and to test for color blindness. A digital video camera recorder (SONY DCR-PC330) was used to record the experiments and the post-experiment questionnaire. The luminance of experimental lab was 487~611 lux, as measured by a Lutron LX-101 Lux meter.

C. Sense of Direction

Using the Santa Barbara Sense of Direction Scale (SBSOD) [5], 10 questions concerning spatial awareness and navigation allowed self-rating, using Likert's seven-point scale, before the formal experiment. Participants responded to each question by circling a number ranging from 1 (strongly disagree) to 7 (strongly agree). Four out of ten statements were positive, e.g., "My sense of direction is very good," "I am very good at reading maps." The other six statements were negative, e.g., "I have a poor memory for where I left things," "I very easily get lost in a new city." These responses were reversed so that a higher score indicated a better SOD. The rating for SOD is calculated by summation of the scores for the ten SOD questions, as a SOD score and then these scores were categorized into two groups as SODG, using the median SOD as the divider for good SOD (GSD) and poor SOD (PSD). In addition, participants sat paper-and-pencil tests for route knowledge (RK), before the experiment. Their RK scores were recorded and categorized into two groups as RKG: good RK (GRK) and poor RK (PRK), based on the test result for route knowledge.

D. Design of Experiment

This study seeks to provide an analytical model of usability of a GMM interface was evaluated using touch screen panels. The usability of the GMM interface was evaluated using a questionnaire for user interface satisfaction (QUIS), upon completion of three route-finding tasks. A four-way factorial design was used to assign each participant all three types of route-finding tasks to each participant and then a post-experiment questionnaire was used to determine user interface satisfaction. The four design factors consisted of: (1) Interface: tablet PC (iPad) vs. smart phone (iPhone), (2) Type: Electronic map (E-Map) vs. mixed map (M-Map, that is, E-map plus satellite), (3) Keyword: use landmark as keyword (Landmark) vs. use district (District), and (4) Input: traditional Chinese hand-written input (hand-written) vs. traditional Chinese phonetic notation keyboard input (phonetic notation). The illustration of the factors Type and Input is shown in Fig. 1. Demographical variables consisted of: (1) gender, (2) route knowledge (GRK/PRK), and (3) sense of direction (GSD/PSD). Forty-eight participants (24 female and 24 male) participated in this experiment. Three route-finding tasks were assigned to each participant; (1) find targets, (2) identify cardinal directions and (3) identify the approximate distances. Cardinal directions were based on 8-sectors model (North, East, South, West, North-East, South-East, South-West and North-West), while approximate distances corresponded to a set of ordered intervals, where the order of symbolic distance values describes distances from the nearest to the furthest [6]. The time to correctly complete the target task, the time to correctly complete the direction task and the time to correctly complete the distance task using a GMM interface were measured (omitted due to limitation of paper length).

The study areas were northern, central and southern metropolitan district of Taiwan, in Taipei, Taichung, and Kaohsiung Cities, respectively. The participants all started from the same point. The mapped area was dynamically updated as the user moved in space.

E. Questionnaire for User Interface Satisfaction (QUIS)

The questionnaire for user interface satisfaction (QUIS) is a structured assessment of usability. It is useful in the early stages of the development of a user-centered design. The International Organization for Standardization (ISO) defines the usability of a product as “the extent to which the product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.” The usability of interactive products is generally defined by the ease with which they can be learned, their effectiveness in use, and the extent to which the user finds them enjoyable to use [14]. In this study, usability is defined by the following parameters: pleasure, interactivity, efficiency, ease of use, ease of recovery from error, memorability, satisfaction, and recommendation.

F. Procedure

At the beginning of the experiment, naive participants were asked to familiarize themselves with the GMM interface. They practiced using the device until they were proficient. Prior to the formal experiment, they were asked to complete an individual background questionnaire, including self-rating of sense-of-direction and route knowledge. One of sixteen combinations of treatment was randomly assigned to one of the participants and the participants were subjected to the route-finding tasks. After the completion of all three route-finding tasks, each participant completed the QUIS using a 10-point Likert’s scale.

III. RESULTS AND DISCUSSION

A. Descriptive Statistics and correlation matrix

The overall user interface satisfaction (UIS) score is calculated by summation of the scores for the eight UIS questions as the UIS score. The descriptive statistics are shown in Table 1. The mean UIS for females (54.0) is higher than that for males (50.6). The participants with GRK have a higher mean UIS (59.4) than those with PRK (46.8). The mean UIS for GSD participants (54.1) is higher than for those with PSD (50.5). The mean UIS for using iPad (56.8) is higher than that for using iPhone (47.8). The mean UIS for using E-Map (55.1) is higher than that for using M-Map (49.5). The mean UIS for using landmark search directly (54.0) is higher than that for not using landmark search, but using district search (50.7). The mean UIS for using hand-written keyword input (55.4) is higher than that for using phonetic notation input (49.2). Based on the eight ordinal-scale items of QUIS, the results of Spearman’s rank correlation between pairwise items are shown in Table 2. It can be seen that there is a statistically significant and a moderately positive correlation between pairwise items.

B. Reliability and Validity

Cronbach's alpha is a coefficient of reliability (or consistency). It is a measure of internal consistency, that is, how closely related a set of items are as a group. A "high" value for alpha is often used (along with substantive arguments and possibly other statistical measures) as evidence that the items measure an underlying (or latent) construct. The results of QUIS in this study indicate a value of Cronbach’s alpha is 0.925 and there is good internal consistency. However, a high alpha does not imply that the measure is one-dimensional. If, in addition to measuring internal consistency, evidence is required that the scale in question is one-dimensional, additional analyses can be performed. Exploratory factor analysis (EFA) is one method of checking dimensionality. The results of EFA for the QUIS indicate that 66.8% of the total variation is explained by only one common factor, which is named as the degree of user interface satisfaction (DUIS). Examination of the goodness-of-fit indices confirms that the confirmative factor analysis (CFA) model has been well designed.

C. Individual differences in UIS

The relationship between SODG, RKG, Gender and UIS were investigated for the three tasks. The two-factor interaction plot is shown in Figure 2. It indicates that females with PSD tended toward a higher UIS than males with PSD; however, no significant difference is evident between females and males in the GSD groups (Fig. 2(a)). Similarly, females with PRK have a higher UIS than males with PRK; both females and males with GRK have nearly the same UIS, on average (Fig. 2(b)). In addition, GRK groups with PSD and GSD have a higher UIS than PRK groups (Fig. 2(c)). There is insufficient evidence of statistical significance (all $p>0.05$) for the two-factor interactions.

D. Analysis of variance and Interaction plots

Based on the results of ANOVA in Table 3 indicate that the significance of the two-factor interaction of Interface*SODG and Interface*RKG ($F=7.151$, $p=0.011$ and $F=4.323$, $p=0.045$, respectively) are all supported. The main effects: Type, Keyword, Input, and RKG are statistically significant ($p<0.05$). To interpret the interaction, comparisons between GSD and PSD groups depend upon whether they use iPad or iPhone. In Fig. 3(a), the PSD group using iPad tended toward a higher UIS than the GSD group, but the PSD group using iPhone tended toward a lower UIS than the GSD group, on average, for GMM. PSD participants prefer using iPad to iPhone, but for iPhone users, GSD participants have a higher UIS than those with PSD. It is interesting to note how sense of direction affects the satisfaction users of the different interfaces. In Fig. 3(b), the GRK group using either iPad or iPhone tended toward a higher UIS than the PRK group, but the PRK group using iPad for GMM tended toward a higher UIS on average, than those using iPhone. Similarly, PRK participants prefer using iPad to iPhone. However, for iPhone users, GRK participants have a higher UIS than the PRK group.

E. Discussion

Kato and Takeuchi [9] argue that individual differences in wayfinding strategies between GSD and PSD female undergraduate participants. GSD participants showed much better performance on route learning than PSD participants [9]. Similarly, our results show that GSD participants have higher UIS than PSD participants on using GMM. While little work has explicitly considered how GRK/PRK groups interact with GMM on iPhone/iPad for UIS. A significant amount of research has explored how route knowledge is best conveyed by both interfaces used in our study. Moreover, a significant effect also has explored how SOD is best communicated with both interfaces. Effective route

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maps must provide information that is necessary and sufficient to make the right choice at each decision point [16]. Agrawala and Stolte [17] argue that for maps on mobile devices it is particularly important that the routes are simplified and extra information is removed. It is consistent with our study that E-map has superior UIS than M-map. Reliability of the questionnaire was tested on 532 undergraduates as participants using internal consistency and split-half methods in Kato and Takeuchi's study [9]. A moderately high reliability was obtained. Similarly, both the reliability (Cronbach's alpha) and confirmative factor analysis model of the questionnaire for user interface satisfaction are good enough in this study. However, only forty-eight participates used in the experiment.

IV. CONCLUSION AND FUTURE WORK

The results of this study have implications for mobile spatial interaction in general. Most GMM users prefer using E-map to M-Map. They also prefer using landmark as keyword to district and prefer using traditional Chinese hand-written input method to traditional phonetic notation input. The poor SOD (PSD) group prefers using iPad to iPhone. The poor RK (PRK) group prefers using iPad to iPhone and the good RK (GRK) group has a higher UIS than the PRK group. It is also important to integrate the impact of the design factors and individual differences on the user performance of mobile spatial interaction. The results of quantitative measurements and subjective assessments will be used as the guidelines to provide a better solution and to meet the demands of usability for mobile spatial interaction applications.

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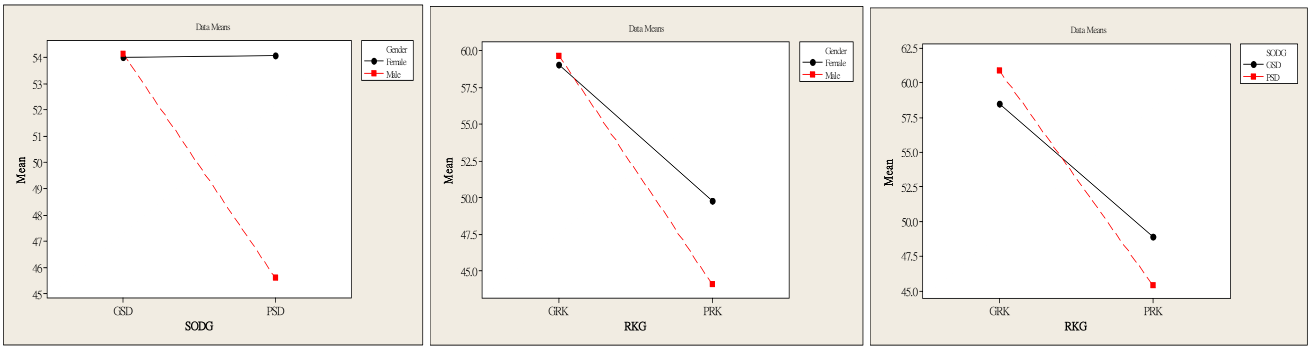
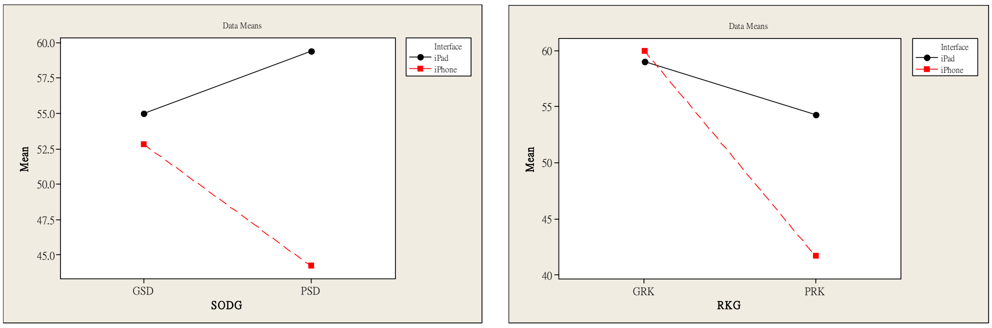
(a) (b) (c) (d)

Figure 1. iPhone screen shots for GMM: (a) using E-Map, (b) using M-Map, (c) keyword search using traditional Chinese hand-written input method, and (d) keyword search using traditional phonetic notation input method (http://m.google.com.tw/maps).



(a) (b) (c)

Figure 2. Interaction effects plot for UIS: (a) Gender*SODG, (b) Gender*RKG, (c) SODG*RKG.



(a) (b)

Figure 3. Interaction plots for UIS: (a) Interface*SODG and (b) Interface*RKG.

TABLE 1. Descriptive statistics of user interface satisfaction (UIS) for the GMM

Variable	Level	n	Mean	StDev	Min	Q1	Median	Q3	Max
Gender	Female	24	54.0	12.85	20	45.50	53.00	66.00	74
	Male	24	50.6	16.71	19	35.00	58.00	63.00	68
Sense of Direction	GSD	24	54.1	15.10	19	48.00	61.00	64.50	74
	PSD	24	50.5	14.71	21	39.25	52.50	62.25	70
Route Knowledge	GRK	21	59.4	10.97	27	54.00	62.00	67.00	74
	PRK	27	46.8	15.31	19	35.00	49.50	61.00	70
Interface	iPad	24	56.8	11.5	27	51.00	60.00	66.75	70
	iPhone	24	47.8	16.61	19	35.50	51.50	61.00	74
Type	E-Map	24	55.1	12.35	27	47.00	56.50	66.00	74
	M-Map	24	49.5	16.79	19	35.50	55.50	62.50	69
Keyword	Landmark	24	54.0	13.30	20	47.50	57.50	63.00	70
	District	24	50.7	16.38	19	39.25	54.00	66.00	74
Input	Hand-written	24	55.4	12.27	24	47.50	57.50	65.25	74
	Phonetic Notation	24	49.2	16.74	19	36.00	55.50	63.00	70

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TABLE 2. Spearman's rank coefficient of correlation of UIS for GMM

Coefficient of correlation (P-Value)	**Pleasure**	**Interactivity**	**Efficiency**	**First priority use**	**Ease of use**	**Error recovery**	**Memorability**	**Satisfation**
Pleasure	1	0.725	0.574	0.644	0.71	0.549	0.427	0.607
	.	.000**	.000**	.000**	.000**	.000**	.002*	.000**
Interactivity	0.725	1	0.752	0.597	0.63	0.61	0.479	0.64
	.000*	.	.000**	.000**	.000**	.000**	.001*	.000**
Efficiency	0.574	0.752	1	0.683	0.548	0.614	0.454	0.666
	.000**	.000**	.	.000**	.000**	.000**	.001*	.000**
First priority use	0.644	0.597	0.683	1	0.647	0.466	0.538	0.746
	.000**	.000**	.000**	.	.000**	.001**	.000**	.000**
Ease of use	0.71	0.63	0.548	0.647	1	0.668	0.389	0.66
	.000**	.000**	.000**	.000**	.	.000**	.006**	.000**
Error recovery	0.549	0.61	0.614	0.466	0.668	1	0.466	0.561
	.000**	.000**	.000**	.001**	.000**	.	.001**	.000**
Memorability	0.427	0.479	0.454	0.538	0.389	0.466	1	0.618
	.002**	.001**	.001**	.000**	.006**	.001**	.	.000**
Satisfation	0.607	0.64	0.666	0.746	0.66	0.561	0.618	1
	.000**	.000**	.000**	.000**	.000**	.000**	.000**	.

* *P-value* <0.01

TABLE 3. ANOVA of UIS for GMM

Source of Variation	**Sum of Square**	**DF**	**Mean Square**	***F***	***P*-value**
Interface	277.42	1	277.42	2.057	0.16
Type	671.621	1	671.621	4.98	.032*
Landmark	590.062	1	590.062	4.375	.043*
Input	1110.106	1	1110.106	8.231	.007**
Gender	226.136	1	226.136	1.677	0.203
SODG	273.547	1	273.547	2.028	0.163
RKG	2016.031	1	2016.031	14.949	.000**
Interface*Gender	73.199	1	73.199	0.543	0.466
Interface*SODG	964.403	1	964.403	7.151	.011*
Interface*RKG	583.021	1	583.021	4.323	.045*
Error	4989.927	37	117.714		
Corrected Total	10368.3	47			

*p<0.05; **p<0.01

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