Concept Designs of Hand Held GPS User Interface

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ABSTRACT: Hand-held GPS can be utilized for route searching, path planning, and serving as an audio and video device to enhance users' experience in their daily life. The purpose of this study is to investigate the user interface design of hand-held GPS, regarding the factors of different display styles and user experience. The experiments were divided into two stages-the preliminary investigation stage and design verification stage. In the first stage, the hierarchy, graphical affordance and interface usability of three commercial GPS products were analyzed. Based upon the results, four concept designs with different display styles were developed, including Traditional, Roller, Sliding, and Folder styles. In the second stage, a 4 (display style) by 2 (user experience) mixed factorial experiment was performed. Ten experienced subjects and ten inexperienced subjects were asked to complete tasks, and then fill in the QUIS questionnaires. The results showed that users are satisfied with simple and clear information hierarchy, which also enhances its learnability. In terms of interface usability, users are accustomed to the traditional touch screen interaction style; however, the sliding style was not accepted by many users. At last, foldable file folders designed with text supports will enable users to obtain better task performance.

Keywords: ***hand-held GPS, user experience (UX), interface style, usability, learnability***

1. Introduction

In addition to accurate positioning for most of the Earth's surface area, Global Positioning System (GPS) can be utilized for route searching, path planning, and navigation aids. According to the industry research by Canalys, the growth curve of the related market continues to rise and there is no decline in the phenomenon [1]. Other reports also project that shipment of GPS devices will grow more than 20% during 2011-2013 to reach around 900 million units by 2013 [2].

Handheld satellite navigation has evolved from a simple navigation system to the mobile multimedia devices, serving as an audio and video device and allowing users to have different experiences in their daily life. Therefore, it is important to ensure its interface design can support the needs and tasks sufficiently, and increase the users' satisfaction.

This study explored the operational problems, the core values of the hand-held satellite navigation products users, from which new concept designs of the user interface were conducted and evaluated. The purpose of this study is triplefold: (1) to explore the differences in use of different brands of handheld satellite navigation system interface, (2) to develop a number of concept designs different from the existing navigation system interface to reduce the user's mental workload, and (3) to propose navigation system interface usability recommendations as design references.

2. Literature review

The research literature covers the user experience, interaction design, and user interface for the follow-up design, and experimental usability evaluation of handheld satellite navigation interface design. The user experience (UX or UE) is a purely subjective feeling in users of a product (service) [3-5]. It is referred to as all of emotions, beliefs, preferences, cognitive impression, physiological and psychological reactions, behavior and achievement before, during, and after the use of a product or system [6]. There are three factors that affect UX: system, user, and context. Narrowly defined, UX is referred to as relations as well as its support mechanisms for consumers of electronic media, including visible user interface, participation and interaction handler and feedback system [4]. With the development of computer technology and social networking technology, UX is much more emphasized in IT application design and has gained a mainstream position in the software design and social network design.

Interaction design refers to the designed interactive products to support people's daily work and life, particularly to create a new UX [7-8]. The general purpose of interaction design includes the design and improvement of the usefulness, ease of use and attraction. The general flow of interaction design includes steps of user research, conceptual design, user behavior model, the flow of the system architecture, the prototype development, user testing, system implementation and testing [9].

Cognitive psychology offers design principles for interaction design, including mental model, perception / reality mapping, metaphor, and affordance so as to effectively reduce the difficulty of user operations and enhance operational effectiveness [10]. Moreover, Nielsen pointed out that the usability of the user interface is not only one-dimensional, but rather consists of five dimensions: learnability, efficiency, memorability, errors, and satisfaction [11]. Kim et al. compared performance of tasks for menus with different breadths using three 3D menus shown on the small display screen of an iPhone simulator. Their study results demonstrated that the performance was best with the revolving stage menu, but there was a non-significant tendency for it to be rated as preferred by the participants [12]. Chen et al. evaluated five PDS menu-icon interface design alternatives by TOPSIS method and found that users preferred the hierarchical and separated menu–icon layout style featuring a two-layer menu structure [13].

Handheld satellite navigation have been continuously improved and refined over many engineers. Its main purpose is to optimize the handheld satellite navigation hardware. This is the same in the design of user interface. It’s worth further investigation whether the current GPS can meet the user’s needs and which interface style of concept design is more satisfactory.

3. Methods

This study is divided into two parts. Stage 1 covers the performance test of existing GPS product to explore whether its interface meets the principles of related literature for improvement. Five basic tasks were designed for subjects to operate in the test. In stage 2, four concept designs were developed and evaluated by tasks and the QUIS (Questionnaire for User Interaction Satisfaction Scale), a tool developed to assess users' subjective satisfaction with specific aspects of the human-computer interface [14-16]. It is executed on a 7-point scale and divided into five parts: overall reaction and system information, screen, terminology and system information, learning, and system capabilities.

3.1 Experiment 1: Survey of the interface of current GPS

36 subjects were invited for the tasks of GPS, of whom 18 were experienced GPS users and 18 without GPS experience. By convenience sampling, all subjects were instructed to operate the handheld satellite navigation. The test consists of five tasks, and at the end of the operation, simple subject interviews were further conducted for exploring the subject’s problems or doubts in the experimental operation.

3.1.1 Experimental Materials

In Experiment 1, three GPS product samples were used, including MIOC710 of MioTechnology Limited, TOMTOM ONEXL, and G-set GV-388 of PAPAGO (Table 1). In the text, they are denoted as MIO, TOMTOM, and PAPAGO.

Table 1. Product specifications of three GPS in Experiment 1

Model	MIOC710	TOMTOM ONEXL	GV-388
Manufacture	MioTechnology Limited	TOMTOM	PAPAGO
Product image			
Screen size	3.5 inches	4.3 inches	4 inches
Graphic system	MIOMAP	NavCore	PAPAGO
Special function	TMC real time road condition update	Touch screen with only one button	Two buttons on the front side

3.1.3 Questionnaire Survey

The questionnaire covers basic information regarding gender, age, experience in using GPS, and weekly use of GPS.

3.1.4 Task Design and Experimental Procedure

In Experiment 1, the subjects' operation time in conducting the tasks was recorded for further analysis. Following were the descriptions of the tasks:
(1) Task1.1: Find the power button, and turn on the satellite navigation system;
(2) Task1.2: Find the time setting page and try to adjust the time;
(3) Task1.3: Find the volume button or page and try to adjust the volume;
(4) Task1.4: Find the button or page for the screen brightness and try to adjust the screen brightness;
(5) Task1.5: Find the page of attractions search and search for some scenic spots in the vicinity.

3.2 Experiment 2: Evaluation of newly proposed hand-held satellite navigation interface

The researchers designed four different types of hand-held satellite navigation user interface and simulated them in real device. Subjects' performance and degrees of satisfaction about four concept designs while executing the five tasks were recorded and analyzed.

3.2.1 Subjects

Ten subjects, five with experience and the other without experience of using GPS, were invited to perform tasks. The subjects were recruited by convenient sampling.

3.2.2 Experimental Materials and System Hierarchy

MioC710 was used for the new interface design. This model uses Microsoft WindowsCENet4.2 and has a 3.5-inch (320 x 240) screen. With the system unlocked, an SD card was imported to execute the system information 32 in a computer to conduct the simulation. In this study, the INI configuration file was used for interface settings, and the icon design was done in Illustrator. Then the ArtIcons was imported for icon size setting and exported the icon files for program operations.

At this stage, the researchers developed four hand-held satellite navigation interfaces with different display styles, including Traditional style, Roller style, Folder style, and Sliding style (Figures 1-4)

3.2.3 Questionnaire survey

The QUIS was executed on a 7-point scale and divided into following five parts [14]:

(1) The overall reaction and system information dimension contains six semantic scales: “bad-good”, “difficult-easy”, “frustrated-satisfactory”, “ineffective-effective performance”, “boring-interesting”, and “rigid-flexible”.
(2) Screen dimension covers questions of font, key function, information structure, and screen

continuity.

(3) Terminology and system information dimension cares about software interface functional terms, the wording of tasks, locations of information presented, input hints, system software processing speed, and error message.

(4) Learning dimension includes learning how to operate the software, find new functions through trial and error, remember commands and function titles, ease in the execution of tasks, description of messages on the screen, and the supplementary reference tools.

(5) System capabilities dimension contains software execution speed, software reliability, software tendency, error correction, and design for different users.

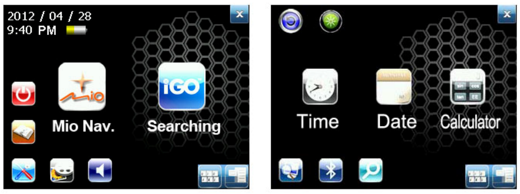

Figure 1. Traditional style GPS interface

Figure 2. Roller style GPS interface

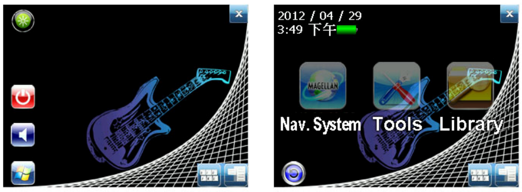

Figure 3. Folder style GPS interface

Figure 4. Sliding style GPS interface

3.2.4 Task design

Five basic tasks for hand-held satellite navigation systems were covered in Experiment 2. The time subjects spent in following five tasks was recorded:

(1) Task 2.1: Find and click the buttons of navigation, attraction search, adjust the time and date, and volume.

(2) Task 2.2: Find the power to turn on and off the GPS.

(3) Task 2.3: Turn on the GPS and then find the notes button and open it.

(4) Task 2.4: Open the Notes, find the keyboard button, and enter “ABC”. Then delete the “ABC” you just enter. Close the keyboard and notes.

(5) Task 2.5: Find the restart button, and then restart the GPS.

3.2.5 Experimental procedure

A mixed two-factor design is adopted at this stage. Each subject performed five tasks in four display styles. To avoid the practice effect in interface operation, different orders of tasks in terms of display styles were arranged and subjects randomly selected one of them to perform the tasks. During the experiment, the researchers adopted the non-intrusive observation to check the subjects’ behavior and recorded on paper. After each interface task was completed, subjects were interviewed for their problems in operating the GPS interface.

4. Results and Discussions

4.1 Experiment 1

There are five tasks in Experiment 1. The task time of these tasks is shown in Table 2.

Table 2. Task time for five tasks in Experiment 1

	GPS experience	MIO	PAPAGO	TOMTOM
Task1.1	With experience	1.79(1.45)	2.54(1.41)	2.42(0.78)
	Without experience	2.96(1.49)	7.23(8.34)	2.38(1.01)
Task1.2	With experience	59.25(62.52)	17.91(10.82)	28.88(17.76)
	Without experience	43.94(42.40)	13.85(8.64)	31.82(25.31)
Task1.3	With experience	3.03(2.64)	39.49(16.67)	13.15(9.72)
	Without experience	2.74(1.20)	11.96(6.97)	13.93(11.17)
Task1.4	With experience	8.19(4.41)	15.97(13.29)	35.55(37.6)
	Without experience	15.99(24.6)	8.05(5.18)	36.36(41.72)
Task1.5	With experience	41.37(39.1)	10.76(3.75)	15.39(7.13)
	Without experience	21.04(15.84)	13.70(5.38)	25.20(8.49)

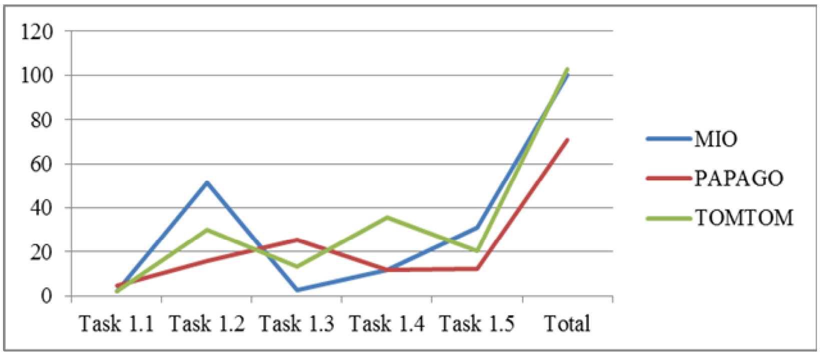

Figure 5. The scatter diagrams for 5 tasks of three GPS models in Experiment 1

4.1.1 General discussion of Experiment 1

From the task time analysis of five tasks, Papago was significantly better than MIO and TOMTOM in time setting (Task 1.2), screen brightness adjustment (Task 1.4) and attraction search (Task 1.5). The difference is due to the structure of Papago's interface. After the subjects operated Papago, they were familiar with the interface structure and could learn it easily. Major findings from Experiment 1 are listed below:

(1) From the operation of power switch (Task 1.1), it can be found that all power switches are special features in hardware of GPS. Users have no problems in operation when they are familiar with it.

(2) For time setting, GPS models of different brands vary in the hierarchy. The suitable position, button or page for this function in system structure, will be explored to meet users' needs.

(3) Similarly, the button or page for volume adjustment varies in different brands. Some adopt push buttons while others use toggle buttons. If there is no hint for the volume adjustment, users would get confused. In later interface design, the feature in hardware design was excluded and a button for volume adjustment was integrated in the graphic interface.

(4) For brightness adjustment, different terminologies were used by different brands (for example, backlight adjustment, brightness adjustment, date night mode, and so on). In the simulation, the terminology was unified while different font sizes were used to examine user's feelings about different font sizes.

(5) The user-centered design principle in Macintosh, which is popular in the interface of smart phones nowadays, was further explored in the next stage. Whether the Sliding style of interface design is suitable for the hand-held satellite navigation was examined. The interface usability and hierarchy in the structure of the hand-held satellite navigation system were the key points for subsequent interface design.

4.1.2 Comparisons of subjects' performance in different GPS models

In Task1.1, subjects were asked to find the power button and turn on the satellite navigation system. Results of ANOVA indicated no significant differences among three GPS models and between subjects with and without experience. In other words, subjects could easily find the power switch to turn on the GPS.

In Task1.2, subjects needed to find the time setting page and then adjusted the time. The result of ANOVA showed significant differences among different GPS models ($F=3.390$, $P=0.047<0.05$) but no significant differences were found in experience variable and the interaction of products and experience. Moreover, LSD Post hoc demonstrated that Papago had a better performance ($M=15.88$, $Sd=9.57$) while MIO had a poor performance which cost subjects a lot more time to set the time ($M=51.60$, $Sd=51.56$).

From the observation in Experiment 1, it can be found that the page for time setting is placed on the top level in MIO. But the initial page of MIO is the map navigation page. To access the page for time setting function, the subjects need to push a button on the side to get back to the top level of functions. Subjects were afraid of making errors or getting lost, causing a much longer time in searching for the time setting button. In the case of Papago, the time setting button is located in the function page. The subjects only needed to find the function page for time setting.

In the task of volume adjustment (Task1.3), there were significant differences in product variable ($F=16.96$, $P=0.000<0.05$), experience variable ($F=7.911$, $P=0.009<0.05$) and their interaction ($F=8.362$, $P=0.001<0.05$). LSD post hoc of product demonstrated that MIO had the best performance ($M=2.88$, $Sd=1.96$); TOMTOM the second ($M=13.54$, $Sd=9.99$); Papago the poorest ($M=25.72$, $Sd=18.84$). The significant difference between MIO and Papago in terms of volume adjustment lies in the affordance of the volume button. In MIO, the volume adjustment button of graphic symbol is located in a remarkably visible place that can trigger intuitive operation. For Papago, there is no graphic symbol to remind subjects of volume adjustment. As a result, it is not easy for subjects to figure out that there is a volume button on the side of the machine.

For screen brightness adjustment (Task1.4), there were significant differences among three GPS models ($F=3.442$, $P=0.045<0.05$), but no significant differences existed in the experience and the interaction variables. Result of LSD post hoc demonstrated that PAPAGO had the best performance because subjects only needed to go back to the function page to adjust the screen brightness. After other tasks, subjects had the short term memory and could easily complete the task. In TOMTOM, there was only the power switch on the machine and other settings should be done in the interface. In the first touch of TOMTOM, most subjects didn't know how to complete the task. In other words, there was too less information in the interface of TOMTOM, resulting in a less smooth operation in screen brightness adjustment.

In Task1.5, subjects needed to find the page of attractions search. Result of ANOVA reflected significant differences in products ($F=3.355$, $P=0.048<0.05$) but experience and interaction didn't reach the significant level. Among three GPS models, PAPAGO had a better performance ($M=12.23$, $Sd=4.68$) while MIO was poor in performance ($M=31.20$, $Sd=30.36$). The attractions searching function can be found in the main menu of PAPAGO. After many tasks, subjects were familiar with the operation in PAPAGO. In MIO, subjects could choose to search attractions by city or surrounding attractions which could be further classified into petrol stations, hospitals, schools etc. This caused subjects a hard time to make a choice between two alternatives, leading to a slower operation.

4.2 Comparisons of different concept designs of hand-held satellite navigation interface

4.2.1 The overall performance of different concept designs

The researchers added the total of five task actions to explore the performance of different concept designs. Significant differences could be found in display style, subject's GPS experience, and their interaction (Figure 6).

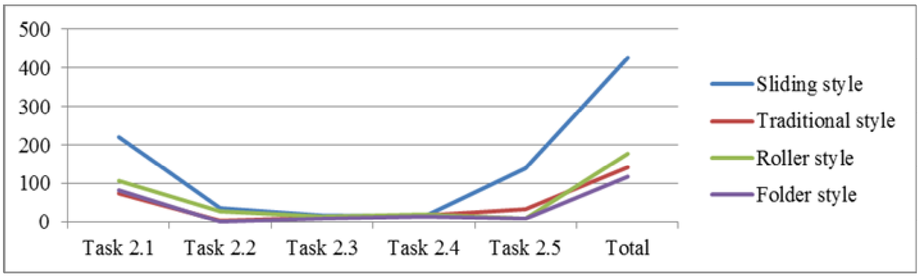

Figure 6. The scatter diagrams for 5 tasks of four concept designs in Experiment 2

Summary of the mixed two-factor ANOVA indicates that there is a significant difference between four interface designs in total performance (F=43.544, P=0.000<0.05). Overall, the style of Folder interface (M = 116.94, Sd = 40.72) is superior to the other three display styles and Sliding style interface is significantly lower than the other three interface styles (M = 426.78, Sd = 246.86). It is due to the fact that users are familiar with Windows system after their prolonged use of personal computers or notebooks and that most experienced GPS are accustomed to the handheld satellite navigation package software. They felt frustrated and were not satisfied with the newly defined Sliding interface even though they might be smart phone users.

Generally speaking, the experienced subjects were accustomed to the use of GPS and had no problems in executing the tasks. The subjects without GPS experience were not familiar with the interface and might get confused in the graphic symbols. If there were no labeling texts to help explain the functions, they might get lost, leading to a poorer overall performance. After the operation of first GPS model, subjects had cognition and short-term memory of the graphic symbols, and performed on later tasks more smoothly. According to the subsequent interview of subjects, most of them expressed that Traditional and Folder styles best met their conventional experience in GPS operation.

4.2.2 Task Time Analysis in Experiment 2

As can be seen in Figure 6, no obvious differences were found in Task 2.2, Task 2.3, and Task 2.4. Consequently, subjects' performance in Task 2.1 and Task 2.5 were analyzed in this section.

Task 2.1 examined the fluency subjects had in operating common functional pages or buttons in four concept designs. There were significant differences in terms of product style (F=16.997, P=0.000<0.05), and subject's experience (F=21.385, P=0.002<0.05), as well as in their interaction (F=6.934, P=0.002<0.05).

LSD post hoc test indicated that subjects had the best performance in searching for commonly used functions in Traditional style (M=73.69, Sd=30.28) but were poor in finding these functions in Sliding style (M=221.29, Sd=120.32). As mentioned earlier, subjects considered the operation of GPS should be like traditional way of handheld satellite navigation but not sliding or moving from page to page on the screen. Similarly, the experience of GPS helped subjects manipulate this task in all styles of interface concept designs. Overall, all subjects were able to recognize most graphic symbols and hierarchical structures in Traditional style and Folder style interface, leading to similar performance in this task. From observation of the experimental tasks, subjects with GPS experience would wait for the system while those without experience would doubt about not having touched the button. Furthermore, the experienced subjects were also frequent users of smart phones. Therefore, their performance in Task 2.1 was significantly better than the inexperienced subjects.

In Task 2.5, subjects needed to find the restart button, and then restart the GPS. Result of ANOVA indicated significant differences among four styles of GPS interface (F=12.554, P=0.000<0.05), between experienced subjects and inexperienced subjects (F=7.700, P=0.024<0.05) as well as their interaction (F=9.096, P=0.000<0.05).

In restarting task, subjects performed the best in Traditional style (M=34.78, Sd=34.97) but had a poor performance in operating Sliding style (M=139.33, Sd=151.19). LSD post hoc test revealed that Sliding style was significantly different from the other three concept designs. The reason is that in Traditional style, the Restart button was positioned under the tool palette, matching the subjects' cognition but in Sliding style, there was no graphic button. Subjects considered that all functions buttons were under the interface framework but ignored the composite button. The switching back and forth in the interface to look for the restart button cost subjects a lot of time to restart the system in Sliding style concept design. When an inexperienced subject couldn't find the restart button, he or she would spend a long time searching for the button in different hierarchies. Similar situation could be found in the Sliding style case. From the observation of Experiment 2, the experienced subjects would check the menu in Task 2.2. Their short term memory helped enhance their performance in this task.

4.3 User Satisfaction (QUIS) in Experiment 2

The ranking order of four concept designs of hand-held satellite navigation systems in QUIS dimensions is Folder style > Roller style > Traditional style > Sliding style (See Figure 7). Moreover, there were significant differences among four styles in five QUIS dimensions.

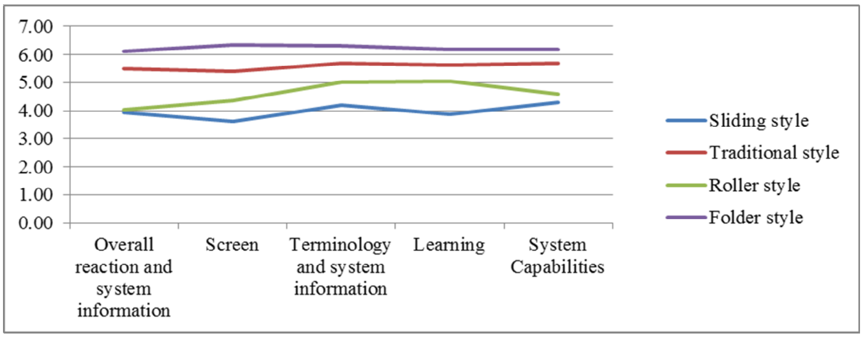

Figure 7. The scatter diagrams for 5 dimensions in QUIS of four concept designs in Experiment 2

The phenomena that Folder style was highly satisfied (M= 6.23 in five QUIS dimensions) but Sliding style was only moderately satisfied (M= 3.99 in five QUIS dimensions) reveals that the accumulated experience in GPS operation had an impact on the cognition of GPS interface styles. Folder style was significantly more satisfied by the subjects than the other three styles in overall reaction and system information dimension. Sliding style changed the operational habit of GPS and was not accepted by the subjects, leading to the least satisfaction in overall reaction and system information dimension.

Similarly, subjects had a higher degree of satisfaction for Folder style (M=6.35, Sd=1.01) but lower degree of satisfaction for Sliding style (M=3.63, Sd=2.30) in screen dimension. The reason is partly due to the fact that Sliding system occupied a big system capacity and utilized a big share of resources, resulting in less smoothness in the screen representation and the lowest degree of satisfaction in screen dimension. On the contrary, subjects were highly satisfied with Traditional style and Folder style mainly because these two systems only changed the structure and had a smooth operation pace.

In the dimension of terminology and system information, Folder style was highly satisfied (M=6.32, Sd=1.05) while Sliding style was only moderately satisfied (M=4.20, Sd=1.89). Such a big difference reveals that small font sizes in Sliding style was not accepted. In Folder style, the functions of navigation and attractions searching were prompted by big graphic symbols and texts, leading to intuitive operation of all tasks and a high degree of satisfaction.

It is the same situation in learning how to use the four interface designs. Though the execution speed might be enhanced, subjects were not adapted themselves to the Sliding style. In Folder style, the texts gave hints for operation and buttons were positioned according to their property, causing smooth operations and higher degree of satisfaction.

In terms of system capabilities, Folder style had the highest degree of satisfaction (M=6.18, Sd=0.82) whereas Sliding style was least satisfied (M=4.30, Sd=1.52). As mentioned before, because Sliding application programs occupied a big share of system capacity, the execution speed was slower and caused the operation less smooth. On the contrary, the interface structure of Folder style matched the subjects' cognition of computers. Such compatibility won the higher appreciation of the subjects.

5. Conclusions and Suggestions

In this study, current GPS models were first investigated to explore the problems users encountered in operating the handheld satellite navigation interface. Based upon the results of the pilot test, four concept designs of GPS interface were developed and verified by tasks and QUIS questions.

The study results revealed that the differences of terminology and graphic symbols in current handheld satellite navigation systems annoyed many users and caused troubles in their recognition. Therefore, it is recommended that manufacturers use consistent or suitable texts to help users figure out the graphical information. Commonly used function buttons should be placed in the prominent place. With clear visual stimulation, users can get the hints at a glance. At last, a real context for users to operate different concept designs needs to be explored in the future.

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