A Study of Information Retrieval of En Route Display of Fire Information on PDA

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Abstract. This study was concentrated on which way is the most convenient for firefighter to get information, comparing among audio display, text display, and combined multi-modal display. Can fire commanders effectively obtain key fire information while they are en route to the fire, especially when they sitting in a moving and bumpy car? The task includes free-browse, free-recall and searching information. The result showed that: (1) Audio only always made firefighter taking the longest time to browse and search, but the introduction of audio display made the two combined displays more quickly to access information, and more easy to remember. (2) Searching in a moving environment took a little longer than searching in lab. (3) Comparing in the lab and in moving car, it was found that searching in a moving environment took a little longer than in lab. (4) It was proved that text display was still a necessary and indispensable way to display information.

Keywords: Information retrieval, Display, PDA, Free-browse, Free-recall, Search.

1 Introduction

The rapid growth of the IT industry during the last few decades has increased demands on mobile devices such as PDAs, cellular phones, and GPS navigation systems. With emerging concepts of context-aware computing, the mobile devices can provide mobile users with timely information by using not only common knowledge but also environmental context such as current time and location [1]. PDA has applied many systems. For example, alerts in healthcare applications [2], navigation system [3]. Auditory system is another important sensory system for getting information, which is the major complement to visual system. Moreover, human responds to auditory stimulus is faster than visual stimulus [4].

For Firefighting, time means life saving. En route display system is a kind of handheld device with mobile communication, which aimed to help fire commander to access the most current fire information as quickly as possible. Purpose of the experiment is to answer the following questions: can fire commanders effectively obtain

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key fire information while they are en route to the fire, especially when they sitting in a moving and bumpy car? Comparing among audio display, text display, and combined multi-modal display, which way is the most convenient for firefighter to get information?

2 Method

2.1 Experimental Environment

Test equipment. An en route display prototype (installed in a handheld PDA device) has been developed as the experimental platform, which could show the current fire related information to fire commanders, such as the address of the building got a fire alarm, the location of the first alarm in the building, and so on. The size of words is based on previous experiment[5]. Based on the result from card sorting experiment, all the fire information has been clustered into three-level menu structure. The first level and the second level are total information (see Fig. 1). The third level is specific information.

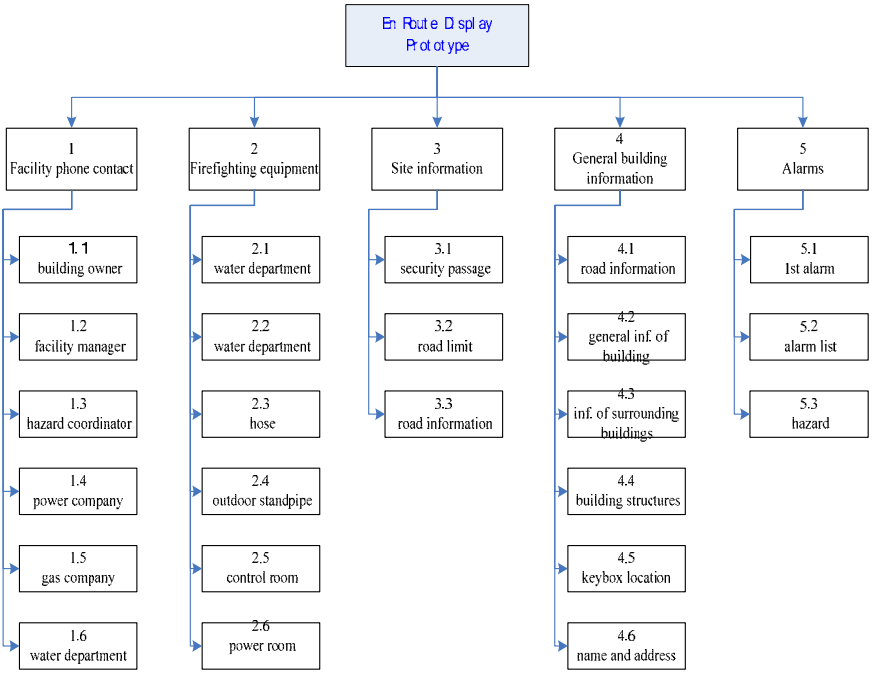

Fig. 1. Content of the first and the second level menu

Fire scenarios. Totally 16 fire scenarios drawn from the previous 3D fire information display prototype[6] were pre-installed in the prototype, supposed to happen in 3 buildings: Camden building, a 45-floor simple structured tower building, and an 8-floor

complex structured hospital building with unregulated shape. 2 of them were Camden building fires (single fire). 7 of them were tower building fires (including 2 SS fires (Single fire seed spread on Single floor), 3 SM fires (Single fire seed spread on Multiple floors)), and 2 MM fires (Multi fire seeds spread on Multiple floors). The other 7 of them were hospital fires (including 2 SS fires, 2 MM fires, and 3 SM fires) were prepared as the scenario pool.

Experimental places. The experimental tasks were completed both in a lab (indoor test part) and in a moving car (outdoor test part). A set of standard usability test room was used as the indoor test place. A Volkswagen sagitar car was used as test car. Driving speed is about 45 kilos/hour. In the test room, firefighters were asked to fulfill two kinds of test tasks (free recall, information searching) by using en route display prototype. In the moving car, one firefighter sitting in co-driver's seat was asked to do a dual-task: the main task is a counting how many street lamps passing by on right side along the road and speak out the number loudly; the secondary task is to finish information searching by using en route display prototype.

2.2 Participants

12 firefighters participated in our experiment. 11 of them aged from 21 to 29, and 1 subject is 35 years old. 6 of them have bachelor degree. 9 of them have more than 5-year firefighting experience. All participants had accomplished all the experimental tasks.

3 Procedure

Each test was conducted by one firefighter and two experimenters. During the test, one experimenter worked as a moderator, the other one was in charge of video recording and note taking. The whole test consisted of three parts: training, test, and interview.

Training experimenter took a couple of minutes to explain 5 key's function on the PDA device so that subjects can know clearly how to use them (up: previous item, down: next item, left: previous level menu, right: next level menu and middle key: updated information) to browse the system and get information.

Test. This part was divided into two stages: test in lab, test in moving car.

Test in lab

1. Task 1 free browse and free recall: firefighter was asked to explore en route system for a few minutes (3-5 minutes) then stopped when he thought he was already familiar with the prototype, and was asked to recall whatever he can remember in his mind. Each firefighter could only try one of the four display ways to explore the en route system.
2. Task 2 Information searching: moderator show four items to firefighter one by one, and ask him using the en route prototype to find the items as quickly as possible. In order to assure firefighter had not only found the location of the item but also remembered the content, after finding the item, he was asked to repeat the content about the item without seeing the information.

Test in moving car

3. Task 2 Information searching: same as the test in lab.

Interview. After the test part, firefighters were asked to evaluate the menu structure, to tell their preference to the four ways of fire information display. Then experimenter asked firefighter several questions.

3.1 Data Analysis of Free-Browse and Free-Recall Task

Free-recall task was to test what firefighters can really get from the en-route display system and what they have memorized.

Experimental design. One way between subjects design was used in this task. There were four ways of information display on en route system, which were audio only, text only, combined text + audio and text + the third level auditory display. 12 subjects were randomly divided into four groups. Each group has 3 firefighters. Each group tried only one kind of four information display ways. They were asked to browse and operate the PDA device freely till they felt familiar with the system and knew the fire related information. Then, they were asked to recall key information from they had browsed. Browsing time, the item number they browsed, and the items they recalled were recorded. All subjects used the same scenario (Camden building fire).

Experimental result. Table 1 showed the numbers of browsed items and average time of free browsing. The first level menu had 6 items, so there are total 6 scores. If subject browsed only 1 item, he would get 1 score. The second level and third level menu had 24 items respectively. It's found that "text only" and "combined text + audio" display are better than other two kinds of display. Subjects spent least time on "combined" display style.

Table2 showed free-recall item numbers under the four different kinds of display conditions. If subject could recall one item correctly, he would get 1 score. It's found that subjects could get more scores using "test only" and "combined text + audio" display than the other two display styles.

Table 1. Free-browse item number and average time

	1st level menu (6 scores including updated inf.)	2nd level menu (24 scores)	3rd level menu (24 scores)	average time for exploring
audio only	5.3	12.3	6	0:05:35
text only	5.3	17	13.3	0:04:40
combined text + audio	5.3	16	13.3	0:03:17
text + the 3rd level audio	5.3	12	10	0:03:41
mean	5.3	14.3	10.67	0:04:18

Table 2. Free-recall item numbers

	1st level menu (6 scores including updated inf.)	2nd level menu (24 scores)	3rd level menu (24 scores)	total number
audio only	0.7	2.7	2	5.4
text only	1	2.3	5	8.3
combined text + audio	3	4.7	1	8.7
text + the 3rd level audio	1	2.3	3	6.3

From the data on table 1 and table 2, we can say firefighters have browsed all the items at the first level, most items at the second level, and about half of the items at the third level. The more items they browsed, the more items they can correctly recalled. But the amount of their memory was still around the limitation of short memory: 7+/-2.

3.2 Data Analysis of Searching Task

Experimental design. Searching task was to test the efficiency of the en route system for firefighter's operations. 2*4 between subjects design was used in this task. Two factors were the places where the en route system was used, and the ways of fire information display. Lab and moving car were used as the two experimental places. Four different display ways (same as mentioned above) were tested to find which way is easier and more convenient to search information.

12 subjects were randomly divided into four groups. Each group has 3 firefighters. Each group used the same way of display as in the browse and recall task to search information.

In the lab situation, each subject was asked to search four items: facility manager, hose, security passage and name and address of the building got a fire alarm. All subjects used the same scenario (hospital fire).

In moving car situation, each subject searched four different items: Power Company, control room, road information and building structure. All subjects used the same scenario (Camden fire).

In this task, subjects were asked to find the item as quickly as possible and repeat detailed content without watching back the PDA screen. The searching time and the percentage of correctly repeated content were recorded.

Experimental result. Table 3 and table 4 showed percentage of correct repetition and searching time in the lab and in moving car. Searching time didn't include subjects' repetition time. Percentage of correct answers means accuracy of subject repeating detailed content. About the percentage of correct answer, 0 meant that subjects could not repeat the detailed content that they found; 1 meant that subjects could repeat part of detailed content; 2 meant that subjects could repeat all detailed content.

It's found that audio display took the longest time to search, and "text + 3rd level auditory display" took the shortest wherever in the lab and in moving car. The results

Table 3. Percentage of correct repetition and searching time in the lab

Percentage of correct answers	audio only	text only	combined text + audio	Text + 3rd level audio
0	16.70%	0	0	0
1	33.30%	25%	16.70%	0
2	50%	75%	83.30%	100%
Searching time	0:00:55	0:00:17	0:00:25	0:00:13

Table 4. Percentage of correct repetition and searching time in moving car

Percentage of correct answers	audio only	text only	combined text + audio	Text + 3rd level audio
0	33.30%	8.30%	8.30%	8.30%
1	33.30%	8.30%	0.00%	16.70%
2	33.30%	83.30%	91.70%	75%
Searching time	0:01:03	0:00:31	0:00:31	0:00:23

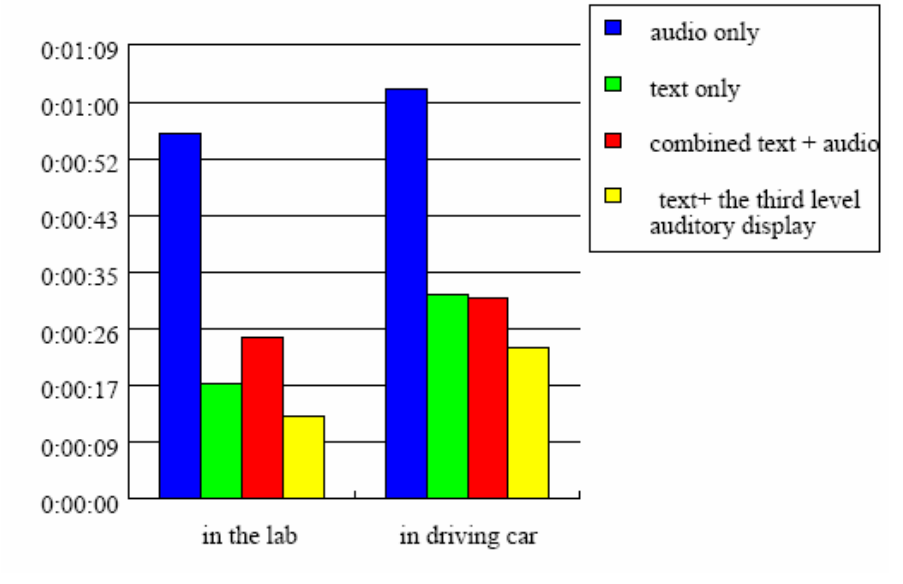

Fig. 2. Comparison of searching time between lab situation and car situation

showed that combined text + audio display were better repeated by firefighters than the other two ways. Among the four displays, there was no significant difference existed.

Fig. 2 showed the comparison of searching time between the lab situation and the moving car situation. It's found there was the same trend among the four ways of

information display, and searching in moving car took about 8 seconds longer than searching in the lab.

4 Interview

The short interview was trying to answer the following questions:

1. What do you think the menu structure? At each level of the menu, which item do you think the most important? Could you sort the items at the same level by their significance? Is there any suggestion to improve the current menu structure?
2. Which way of showing fire information do you prefer to choose when you are using the en route prototype on the way to the fire scene? Why?
3. Do you think the information shown in the system is easy to remember? How much information can you remember each time?
4. Do you think the fire information is easy to find?
5. For the button of updated information, what do you think it, useful, or not?
6. How do you think the en route information display, is it useful, or not? Why?
7. Is there any other suggestion to the prototype?

4.1 Subjective Ratings to the Four Display Styles

From Table 5, we can say most of users prefer combined visual and audio display. (answer to the question 2)

Table 5. Preference to the four display styles

	audio only	text only	combined text + audio	Text + the third level auditory display
in the lab	0	16.70%	66.70%	16.70%
in moving car	8.33%	33.30%	41.70%	16.70%

4.2 Subjective Ratings to Menu Sequence

1 means the most important, 5 means the least important.

Some firefighters said the most important item should be put on the first line, but at the first level menu the alarms was put on the bottom line although it was ranked the most important by everyone (see Table 6).

Table 6. Preference to the first level menus sequence

	1 Facility phone contact	2 Firefighting equipment	3 Site information	4 General building information	5 Alarms
mean	3.5	3.2	3.8	2.6	1.9

For the sorting of 2nd level and 3rd level menu items, it was found that at each category firefighters' rating was consistent with the current sorting in Table 7. Combining the data in Table 6 and 7, to answer the first question about the menu structure, we think the current one is good enough except two things: 1) alarms should be put on the first line at the first level. 2) Security passage should be moved from "4 General building information" to "3 site information".

Table 7. Preference to the second level menus sequence

	1.1 building owner	1.2 facility manager	1.3 hazard coordinator	1.4 power company	1.5 gas company	1.6 water department
mean	1.8	2.6	3.2	3.9	4.3	5.3
	2.1 fire equipment	2.2 equipment shutoff	2.3 hose	2.4 outdoor standpipe	2.5control room	2.6 power room
mean	1.9	3.3	3.4	3.4	3.9	5
	3.1 security passage	3.2 road limit	3.3 road information			
mean	1.4	2.3	2.3			
	4.1 occupants	4.2general inf. of building	4.3inf.of surrounding buildings	4.4 building structures	4.5 keybox location	4.6name and address
mean	2.8	2.4	4.6	3.5	4.5	2.4
	5.1 1st alarm	5.2 alarm list	5.3 hazard			
mean	1.4	2.2	2.4			

5 Conclusion

In order to answer how useful the en route information display system for firefighters' information accessing, current situation understanding, and decision making, we did a series of tests to investigate the efficiency of the system, to compare different display ways including audio, text, and their combinations to find the most appropriate one. Based on the data, and the subjective ratings, we can summarize our findings as follows:

1. En route information display system was useful to help firefighter get the critical fire information and make decision more quickly and accurately.
2. Comparing the four information display ways: audio only, text only, audio + text, and text + the 3rd level audio, audio only always made firefighter taking the longest time to browse, search, but the introduction of audio display made the two combined displays (text + audio, and text + 3rd level audio) more quickly to access information, and more easy to remember.

The reasons making audio display the worst could be: a. the voice message was not clear enough for firefighter to hear, especially in moving car; b. 3-level information structure is difficult for people to understand just by listening. But the data also showed that, after training, if firefighter has already got the information structure in mind, the convenience of operating with audio way will be the same as operating the system with other way.

1. Comparing the two situations of using the en route system: in lab, and in moving car, it was found that searching in a moving environment took a little longer than searching in lab.
2. It was proved that text display was still a necessary and indispensable way to show information. The reason was that, even there was a voice message playing, people still need to look at the text to make sure what they heard and understand was correct, especially for the building address, alarm location, and the contactors' name, and so on. Because those information is really critical for firefighting and life saving.

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