A Study of Fire Information Detection on PDA Device

Xianghong Sun[1], Weina Qu[1], Thomas Plocher[2], and Li Wang[1]

[1] State Key Laboratory of Brain and Cognitive Science, Institute of Psychology, Chinese Academy of Sciences, Beijing 100101, China
{quwn,sunxh,wangli}@psych.ac.cn
[2] Honeywell ACS Labs, Minneapolis MN 55418, USA
tom.plocher@honeywell.com

Abstract. This study was concentrated on 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. The result showed that: (1) Audio only always made firefighter taking the longest time to information detection, 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. (2) It should be clarified that en route system could be used very well either in quiet and static environment, or in a moving and a little bumping environment if user could get some training before using it.

Keywords: Information detection, PDA, fire.

1 Introduction

Fire incidents came into being with the discovery and utilization of fire and are closely linked to the advancement of human civilization [1]. Firefighter will know about details after arriving firing spots today. For saving time, a handheld PDA device has been developed, which could show the current fire related information to fire commanders. Fire alarm system is an essential part of high buildings in modern times, which helps firefighters' detection more efficiently and reduces the casualty [2]. Ko's research focused on proposed robust fire-detection algorithm that is installed in home network server [3].

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. Purpose of the experiment is to answer the following questions: is the information they can get from the en route display system really helpful for firefighting decision making? In other words, comparing with the situation without en route display system, is the en route information really help the incident commander assess the situation and make decisions any faster or more accurate? Could firefighters be "primed" by en route information?

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2 Method

2.1 Experimental Environment

A handheld PDA device has been developed as the experimental platform, which could show the current fire related information to fire commanders. The size of words is based on previous experiment [4] .Totally 16 fire scenarios drawn from the previous 3D fire information display prototype [5] were pre-installed in the prototype. The experimental tasks were completed both in a lab and in a moving car.

Since the PDA device was not dedicated for the en route display system, all the keys and buttons used in the experiment were four arrow keys for going up/down to the upper/lower level menu, and one middle key for getting updated information, the other keys became to be distracters. In order to avoid interrupting the application of en route prototype during the test, all the other functions were closed, and all the other keys and buttons were masked by plaster (see Fig. 1).

Fig. 1. PDA device as the experimental platform

Experimental places divided two parts: in a lab and in a moving car. In the test room, firefighters were asked to finish fire information detection task by using PDA prototype and 3D fire information display prototype. In the moving car, firefighters were asked to do a dual-task: the main task is to counting how many street lamps passing by on right side the road and speak out the number of lamps loudly; the secondary task is to finish fire information detection task using PDA prototype.

2.2 Participants

12 firefighters aged from 21 to 35 years participated in our experiment. 9 of them have more than 5-year firefighting experience. 6 of them have bachelor degree.

3 Procedure

Test part was divided into three stages: test in lab, test in moving car, and test in lab with 3D prototype.

Test in Lab

1. First alarm and fire spread finding (first on PDA then on PC touch screen): firefighter was exposed to four different scenarios (using hospital fires: SS fire, and SM fire) one by one. Each scenario was corresponding to one kind of displays: audio only, text only, combined text +audio, and partly combined text + audio. The display order was counterbalanced. For each scenario, firefighter was asked to find the location of the first fire alarm, and the fire spread by using en-route display as quickly as possible, task completion time was recorded as the performance of en route system. Then he was asked to go to the 3D fire information display system, which was used to compare the efficiency in the experiment of 2006[5], to find the location of the first alarm and the fire spread again. Task completion time was also recorded as the performance of 3D fire information display prototype.

Test in Moving Car

2. First alarm and fire spread finding on PDA: procedure and the task requirement is the same as the task 3 in the lab. Also four scenarios (tower building fires: SS fire, and SM fire) was exposed to firefighter one by one. But firefighter was only asked to find the first alarm and the fire spread on PDA device. Task completion time was recorded as the performance.

Test in Lab again:

3. First alarm and fire spread finding on touch screen: Just after the test in car and going back to the lab, only one scenario (the last one of the four scenarios used at the fifth step) was exposed to firefighter. The time of finding the location of first alarm and the fire spread was recorded as the performance.
4. First alarm and fire spread finding: A MM fire (multi fire seeds spreading on multiple floors) was exposed to firefighter, and record the task completion time both with en route system and the 3D information display prototype.

3.1 Data Analysis of Fire Detection Task

This task was to test whether en route system help the incident commander assess the situation and make decisions any faster or more accurately and which way of information display was more helpful.

Experimental design. 2*4 within 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 were the same as mentioned above.

Each firefighter was asked to complete 8 scenario fire detections (including locating the first fire alarm and judge the fire spread). 4 of them (hospital fires: SS or SM) were detected in the lab, and the other 4 (tower building fires: SS or SM) were detected in a moving car. Each scenario was corresponding to one kind of display style. The display order of the four scenarios and the matching pair between scenarios and the ways of information display were counterbalanced. For each subject, the test in the lab went first, and then followed by the test in moving car.

During the test in car, as described in the experimental environment part, firefighter needs to fulfill a dual-task: counting as a distracted task was used as main task, and fire detection is the secondary task.

Experimental Result

Test in Lab

Fire detection with en route system. Table 1 showed mean and std. deviation of task completion time in finding first alarm when using en route prototype. Task completion time was recorded from choosing the scenario by moderator to find the first alarm item. It's found that "audio only" display was the worst way. It took the longest time. (F (3) =25, p=0.00). Among the other three display styles, there was no significant difference existed.

Table 1. Task completion time in finding first alarm task with PDA

	audio only	text only	combined text + audio	text + 3rd level audio
Mean of task completion time	0:00:50	0:00:11	0:00:09	0:00:06
Std. Dev.	0:00:26	0:00:11	0:00:07	0:00:02
N	12	12	12	12

Table 2 showed mean and std. deviation of task completion time in finding fire spread when using en route prototype. Task completion time was recorded from just finding the first alarm to finding the fire spread item. Among the four display styles, Both table 1 and table 2 showed the audio display took the longest to fulfill the fire detection task, but there was no significant difference existed.

Table 2. Task completion time in finding fire spread task with PDA

	audio only	text only	combined text + audio	text + 3rd level audio
Mean of task completion time	0:00:15	0:00:03	0:00:04	0:00:09
Std. Dev.	0:00:24	0:00:01	0:00:04	0:00:18
N	12	12	12	12

Fire detection with 3D information display prototype. Table 3 showed mean and std. deviation of task completion time in finding first alarm when using 3D information display prototype. Among the four display styles, there was no significant difference existed.

Table 4 showed mean and std. deviation of task completion time in finding fire spread when using 3D information display prototype. Among the four display styles, there was no significant difference existed.

Usefulness of the en route information display system. In our previous experiment conducted in 2006 [5], it's found that, without the help of en route system participants didn't finish fire detection task within 30s. In this experiment, combining the data in table 3 and table 4, we found all subjects could finish all the tasks no more than 30s when using "Text + the third level auditory" display for SS or SM fires.

Table 3. Task completion time in finding first alarm task using 3D prototype

	audio only	text only	combined text + audio	text + 3rd level audio
Mean of task completion time	0:00:24	0:00:17	0:00:24	0:00:11
Std. Dev.	0:00:25	0:00:18	0:00:25	0:00:05
N	12	12	12	12

Table 4. Task completion time in finding fire spread task using 3D prototype

	audio only	text only	combined text + audio	text + 3rd level audio
Mean of task completion time	0:00:45	0:00:22	0:00:24	0:00:19
Std. Dev.	0:00:50	0:00:14	0:00:21	0:00:16
N	12	12	12	12

Test in Moving Car

Sitting in a moving car, firefighter was asked to do a dual-task: counting street lamps loudly + fire detection. In this situation, moving and bumping made text on screen difficult to read, and dual-task made attention resource very limited to fire detection task. One hypothesis was that audio display would help firefighter to access information and understand it easily and quickly. Especially for the situation that user's hands were not available for operating the en route system, which happened rarely in the lab situation. Therefore, except for the four kinds of displays we used in lab, an auto-play way was added as the fifth level of the information display ways. Here the auto-play meant that the fire information could be automatically play by voice message and any key/button operation was not necessary, which ensure firefighter could get all the information even if they had no hand, or had no time to activate the en route system. So, for each firefighter in this test part, he would do 5 fire scenarios and each scenario was corresponding to one kind of display styles. There are total 5 display styles, including auto-play audio way. The order of the 5scnarios was counterbalanced.

Table 5 showed mean and std. deviation of task completion time in finding first alarm when using en route system. The time was recorded from choosing the scenario by moderator to the time point of having found the first alarm item. It's found that finding first alarm using "audio only" display was the worst way. It took the longest time ($F(3) = 4.4$, $p = 0.01$). The bottom half in table 5 showed mean and std. deviation

Table 5. Task completion time in fire detection using en route system in car

task completion time		audio only	text only	combined text + audio	text + 3rd level audio
the first fire alarm	Mean	0:00:40 **a	0:00:13	0:00:05	0:00:05
	Std. Dev.	0:00:54	0:00:10	0:00:02	0:00:03
	N	12	12	12	12
the fire spread	Mean	0:00:08 **b	0:00:03	0:00:03	0:00:03
	Std. Dev.	0:00:05	0:00:02	0:00:01	0:00:01
	N	12	12	12	12

a: F (3)=4.4 p=.01; b: F (3)=9.2 p=.00.

of task completion time in finding fire spread when using en route system. It's found that using "audio only" display to find fire spread was the worst way too. It took the longest time also (F (3) =9.2, p=0.00).

Counting Task Performance

This task aims to simulate an attention distracter, which can interrupt how the subject finished detection task.

All the firefighters were required to count how many street lamps were passing by on right side along the road and to speak out the number loudly. Participants began to counting task when the recorder asked the participants to do it. After the experiment, the experimenter and the recorder count the number of street lamps in all together.

From the table 6, we can see that S1 and S10 have the worst counting task performance, 67% and 69%, respectively. Most of the participants have good counting task performance. Someone even counted the number absolutely correct! The mean of correct percentage is 89%.

Table 6. Percentage of correct counting street lamps in moving car

Subjects	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Percentage of correct answer	67%	90%	97%	96%	89%	85%	92%	100	99%	69%	88%	91%

Comparison of the two test situations: in test room vs. in moving car. Fig 2 and Fig 3 showed the comparison of task completion time of finding first alarm and fire spread task between lab situation and car situation. They showed the same trend wherever in the lab or in moving car. It seemed that subjects could take shorter time in car to fulfill the fire detection task than to do it in the lab.

There could be two reasons for the result: 1) The en route system was not so complicated to operate and understand, so even in a moving and bumping situation, it was

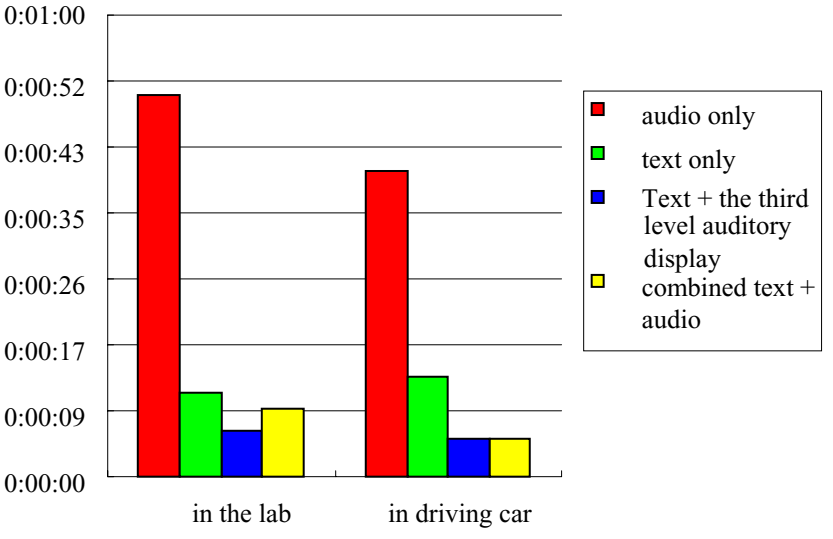

Fig. 2. Task completion time of finding first alarm

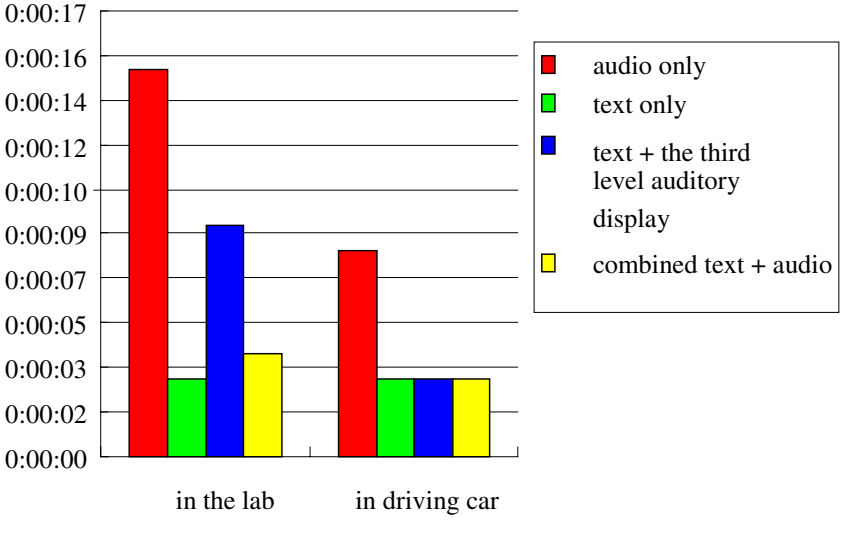

Fig. 3. Task completion time of finding fire spread

still easy for firefighter to use. 2) There perhaps existed a training effect. In our experiment firefighter always completed the tasks in the lab first and then went through the rest tasks in car, which probably made them more and more familiar with the PDA device.

Comparison of the two auditory displays: auto-play vs. play by manual control. For the auto-play display, mean of the task completion time is 2 minutes 52 second. 8 subjects thought automatic style wasted much time to find useful information.

Test in Lab Again (Complicated Fire Test)

Most scenarios used in lab test and in car test were SS fire, or SM fire, which were easy for firefighters to understand the current fire situation. In order to find the advantages and disadvantages of en route system, and to find the appropriate conditions that en route system could be made the best use of, after completing the 8 fire scenarios and firefighter's going back to the lab firefighter was asked to fulfill fire detection task to a complicated fire (hospital or Camden fires: MM fire). The task completion time was recorded. 12 subjects were divided into three groups, and each group did one scenario using one of the four kinds of display styles. After they finished finding first alarm and fire spread by en route system, they would be asked to use the 3D FirstVision graphical display prototype to do the fire detection task.

Table 7 showed mean and std. deviation of task completion time of fire location when using en route system. Result was similar as above. Audio display took the longest time (F (3) =71.03, p=0.00). Among the other three display styles, there was no significant difference existed. For the performance of fire spread, among the four display styles, there was no significant difference existed.

Table 8 showed the task completion time of fire detection when using 3D prototype. Among the four display styles, there was no significant difference existed.

Table 7. Task completion time in fire detection using en route system

task completion time		audio only	text only	combined text + audio	text + 3rd level audio
the first fire alarm	Mean	0:00:12 **	0:00:03	0:00:04	0:00:02
	Std. Dev.	0:00:1	0:00:0	0:00:01	0:00:0
	N	3	3	3	3
the fire spread	Mean	0:00:4	0:00:2	0:00:2	0:00:3
	Std. Dev.	0:00:4	0:00:1	0:00:0	0:00:1
	N	3	3	3	3

**F (3) =71.03, p = .00.

Table 8. Task completion time in fire detection using 3D prototype

task completion time		audio only	text only	combined text + audio	text + 3rd level audio
the first fire alarm	Mean	0:00:16	0:00:12	0:00:26	0:00:14
	Std. Dev.	0:00:12	0:00:10	0:00:16	0:00:4
	N	3	3	3	3
the fire spread	Mean	0:00:19	0:00:53	0:01:01	0:00:31
	Std. Dev.	0:00:07	0:00:09	0:00:43	0:00:16
	N	3	3	3	3

For complicated fires, subjects couldn't finish all the tasks within 30s. And few of the 12 firefighters could find there were 2 fire seeds in the test scenario.

4 Conclusion

In order to answer how useful the en route information display system for firefighters' 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, 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 understand the information, 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.
3. Comparing the two situations of using the en route system: in lab, and in moving car, it was found that for the task of fire information detection, it took shorter when it was in moving car than in lab, but there was no statistical difference. This result didn't mean people could do a better job in car than in lab. It should be clarified that en route system could be used very well either in quiet and static environment, or in a moving and a little bumping environment if user could get some training before using it.

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