Application of Natural Language in Fire Spread Display

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Abstract. How to express fire spread efficiently and effectively to firefighters was an important issue. The present study aimed to investigate how to present the fire alarm information, focusing on whether natural language alarm presentation was better than the alarm list presentation. Objective method and subjective evaluation were used to compare the difference among different expressions. The results revealed that natural language was better than alarm list in described a fire spread situation, and the effect was more robust when spatial information was added. Traditional alarm list was more accuracy than other forms, but it cost more time to read and comprehension. So natural language with spatial information will be recommended to the future design of fire alarm system.

Keywords: natural language, alarm list, fire spread display, comprehension.

1 Introduction

Time is one of the most important issues in firefighting. Firefighters need to access fire information as quickly and accurately as possible. How to present fire spread efficiently and effectively to firefighters was an important issue for relative product design. In previous studies, we explored some interactive styles of how to present information in fire situation display systems [1, 2], but we still did not know the role of language structure in comprehension of fire spread display.

The production and reception modes of natural language are crucial issues in human-computer dialogue. Le Bigot et al. examined the effects of user production and user reception modes on natural language human-computer dialogue. They found the most efficient configuration for interacting in natural language would appear to be speech for production and system prompts in text, as this combination decreases the time on task while improving dialogue involvement [3]. We also found the similar results in an En Route display of Fire Information [4]. With advances in computer technology, text analysis allows researchers to reliably and quickly assess features of what people say as well as subtleties in their linguistic styles [5]. Text Analysis offers optional solutions for information extraction and natural language processing. People always display adaptive language behaviors during human computer interaction [6]. Based on these result, how to express the fire spread situation became an important question.

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This study aimed to investigate how to present the fire alarm information, focusing on the effect of language structure on fire scenarios comprehension. We adopted an objective choice task and a subjective evaluation task to compare four different presentation forms: Alarm List, Integrated Alarm List, Natural Language and Natural Language with Spatial Information. The following questions were needed to answer: could natural language presentation provide enough information as alarm list, and help participants to obtain fire spread information accurately? Which form could be processed most quickly? Is it useful to add spatial information in natural language form?

2 Method

One factor with four levels design was used to determine the effect of different fire alarm presentations. Objective method and subjective evaluation were used to compare the four presentation forms. The main task of participant was to choose one correct fire scenario from four choices after reading/listening this fire scenario. The response accuracy, response time, times of switch between description and simulation, description viewing time and simulation viewing time were recorded.

2.1 Participant

12 firefighters from two fire brigade participated in this experiment, aged from 24 to 29. All reported normal or corrected vision.

2.2 Materials

4 presentation forms were used to express fire spread situations. The examples of them were giving in Table 1. Form 1 was a traditional alarm list, used as a baseline. It only included specific location and time of every activated smoke alarm. Form 2 was an integrated alarm list, which integrated information of smoke detectors in the same floor. Form 3 was a natural language alarm. Temporal and spatial information were integrated in to a whole sentence, like firefighters used to describe a new fire to their colleagues. Form 4 a natural language alarm with spatial information. The spatial information of the first detector was included in this form in order to investigate the value of supplementary spatial information.

In the learning part, 12 fire scenarios were used as materials in this experiment, including 8 one origin fires and 4 two origin fires. Each scenario was displayed in 4 forms as described above, so 48 presentations were prepared all together in this test. All 48 presentations were divided into four groups by Latin square method. Each group included 12 scenarios and every three scenarios used one presentation form in order to counterbalance the difficulty of 12 scenarios and their description forms. Each participant was arranged to choose one group material randomly to complete the test. The sequence of 12 scenarios was randomly presented.

Table 1. Examples of 4 forms used to express fire spread situations

Forms	Example
Form 1 Alarm list	14:22 ground floor, Break 026 14:23 ground floor, Corr 030 14:23 ground floor, Corr 030 14:23 ground floor, ELEC 028 14:25 Floor 1, ELEC 134 14:25 ground floor, Corr 030 14:25 ground floor, Corr 030 14:25 floor 1, Corr 130 14:25 floor 1, Corr 130
Form 2 Integrated Alarm list	At 14:22, first smoke detector in Break 026 of ground floor was activated. At 14:23, 3 additional detectors in ground floor were activated. At 14:25, smoke detector in Elec 134 of floor1 was activated, 2 additional detectors in ground floor were activated. At 14:26, 2 additional detectors in floor1 were activated
Form 3 Natural Language	At 14:22 smoke was first detected on the Ground Floor in Break Room 026. It spread along the corridor to Room 030. At 14:25, smoke spread to Floor 1 near Room 130.
Form 4 Natural Language with Spatial Information	At 14:22 smoke was first detected on the Ground Floor in Break Room 026.,which was at northwest of the building. It spread along the corridor to Room 030. At 14:25, smoke spread to Floor 1 near Room 130.

In the testing part, four simulated animations were produced for each scenario to test the comprehension of firefighter for each scenario. One was a correct simulation which matches the scenario description, while the other three were false simulations with little mistake. The precondition for setting false simulations was that the number of activated detectors in correct simulation was equal to that in false simulations. In false simulation 1, only the activated time of some smoke detectors was different from the correct simulation. In false simulation 2, the first alarm was in different location of the same floor. In false simulation 3, the first alarm was in the different floor. Four simulated animations were showed on the four monitors randomly during the experiment.

2.3 Procedure

Participants were comfortably seated in an instrumented room (See figure 1). Firstly, scenario descriptions were presented in two ways in the same time, the text information was presented on the first monitor and the audio information was presented by

earphone. Then, the scenario descriptions disappeared and four simulated animations appeared on the four monitors separately. Participants' task was to make sure which simulation was matched with the description presented before. They were required to press the key marked "1", "2", "3", or "4" mapping to the monitor marked "1", "2", "3", or "4" to choose the correct answer. They could switch between the description and the simulation as they wish by pressing the "TAB" key during the task.

Fig. 1. Picture of experiment environment

There were three stages in the whole experiment: practice, test and interview. Before the formal test, participants have to practice using an additional scenario. Four expression forms were tested in this scenario. Participants could ask any question during this stage. In the test stage, 12 experimental scenarios were tested in four presentation forms. This stage was comprised of twelve trials. Test trials were presented in a new random order for each participant. After all the test trials were completed, participants were asked to rank the order of the four expression forms based on which one was easier to understand and to explain the reason.

3 Results

Six dependent variables were recorded for further analyze, including percentage of correct response, response time, description viewing time, simulation viewing time,

switch times between description and simulation, and subjective ranking data. The data were analyzed with SPSS 13.0 using single-factorial analyses of variance with repeated measures. The effect of four expression forms (Alarm List, Integrated Alarm List, Natural Language and Natural Language with Spatial Information) was tested.

The statistical result of percentage of correct responses revealed a marginally significant effect of expression form, $F(3, 33) = 2.73$, $MSE = .07$, $p < .1$. Paired comparisons reflected that only the difference between alarm list (.86) and integrated alarm list (.56) was significant, $t(11) = 3.52$, $p < .01$. See Fig.2 for details.

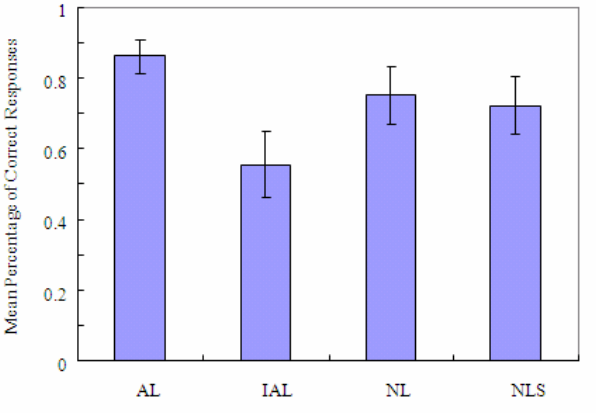

Fig. 2. Mean percentage of correct responses in each expression forms. Error bars represent standard errors. (AL: Alarm List; IAL: Integrated Alarm List; NL: Natural Language; NLS:Natural Language with Spatial Information).

The data of response time (duration between scenario description onsets and participants made choice) revealed no significant effect of expression forms, $F(3, 33) = 1.38$, $MSE = 2915.75$, $p = .27$. No significant result was detected in simulation viewing time, $F(3, 33) = 1.30$, $MSE = 2426.67$, $p = .29$.

The data of scenario description viewing time showed no significant effect of expression form, $F(3, 33) = 1.73$, $MSE = 216.48$, $p = .18$. Paired comparisons reflected that only the difference between alarm list (54.66 ms) and natural language with spatial information (41.13 ms) was significant, $t(11) = 2.22$, $p < .05$.See Fig. 3 for Means and SEs.

No significant effect of expression form was showed in time of switch revealed no significant effect, $F(3, 33) = 2.09$, $MSE = 2.03$, $p = .12$. But paired comparisons reflected that the difference between alarm list (5.35) and natural language with spatial information (4.25) was significant, $t(11) = 2.30$, $p < .05$, and the difference between integrated alarm list (5.59) and natural language with spatial information (4.25) was marginally significant, $t(11) = 1.83$, $p = .09$. See Fig. 4 for details.

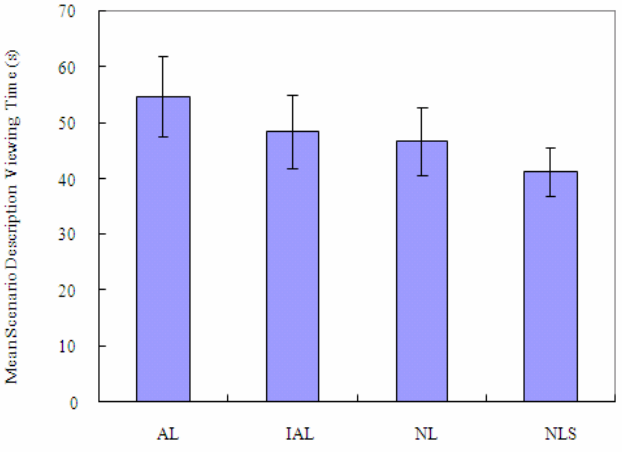

Fig. 3. Mean scenario description viewing time in each expression forms. Error bars represent standard errors.

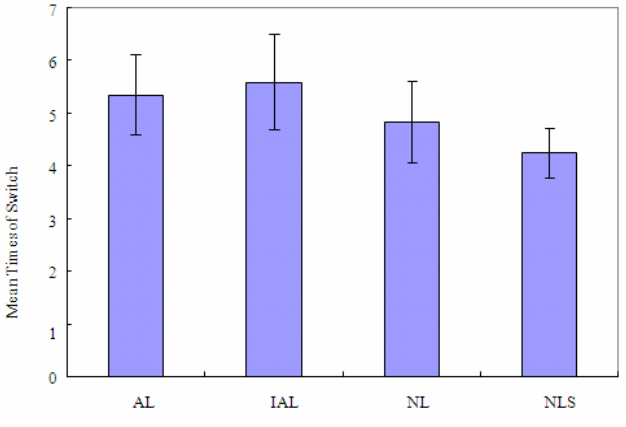

Fig. 4. Mean Times of Switch in each expression forms. Error bars represent standard errors.

The data of ranking scores were also analyzed. There was a marginally significant effect of expression forms, $F(3, 33) = 2.90$, $MSE = 1.44$, $p = .05$. Paired comparisons reflected that the difference between integrated alarm list (1.75) and natural language with spatial information (3.17) was significant, $t(11) = 3.74$, $p < .01$. The difference between integrated alarm list (1.75) and natural language (2.67) was marginally significant, $t(11) = 2.20$, $p = .05$. The difference between natural language(2.67) and natural language with spatial information (3.17) was also marginally significant, $t(11) = 1.92$, $p = .082$. See Fig. 5 for details.

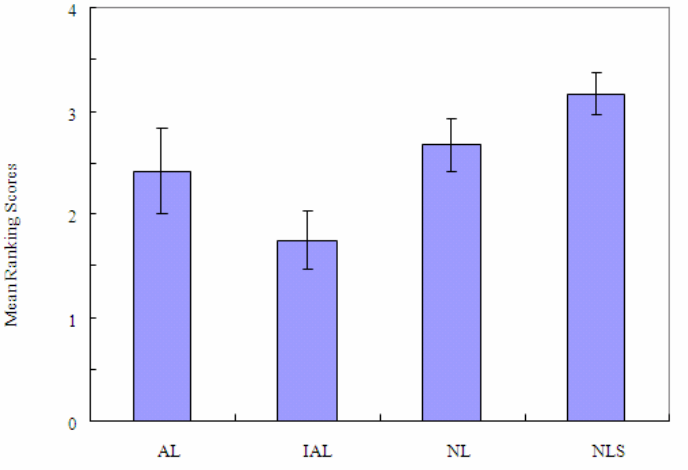

Fig. 5. Mean ranking scores in each expression forms. Error bars represent standard errors.

4 Discussion

The main findings showed that alarm list was better than integrated alarm list in accurate rate. The reason may be that integrated alarm list omitted some key information, so participants did not have enough information to make accurate responses. However, the difference between natural language and alarm list was not significant, neither did difference between natural language with spatial information and alarm list. Therefore it could be inferred that spatial and temporal integration in natural language provided enough information for participants to make correct responses.

Our focus was on whether natural language can help participants react quickly. The following speed indexes were considered: times of switch, scenario description view time, scenario simulation view time and response time. For response time, natural language with spatial information was processed quickly. Participants spent less viewing time when scenarios presented in natural language than in alarm list, especially in natural language with spatial information form. They spent the longest time to view the simulations when the scenarios were presented in integrated alarm list. Participants need to switch from description to simulation more often when scenarios were presented in integrated alarm list than in natural language with spatial information.

Four forms of fire scenario presentation were discussed respectively as below.

For the traditional alarm list, its accuracy of response was the highest one. But its response time was longer than natural language with or without spatial information. There was some trade-off in this description form. Further analyze showed its description viewing time was the longest one among four description forms. One reason for high accuracy and long description viewing time of traditional alarm list was it contained all information about a scenario, so its accuracy was high. But alarm

list was too prolix to remember, so participants spent more time to view its description, switched much more times to choose correct simulation.

For the integrated alarm list, its accuracy of response was the lowest one. And its response time was the longest one among the four description forms. The subjective evaluation score of this form was also the lowest. It was the worst form among four expression forms. Compared with other forms, integrated alarm list missing some spatial and detail information in each floor. It was the hardest one to comprehension, so participant had not enough cues to judge which simulation was the correct one.

For natural language with or without spatial information of origin fire point, it was better than integrated alarm list in accuracy or response time. The response time, description viewing time and simulation viewing time of natural language with spatial information was shortest among four forms. So, for objective speed indexes, natural language was better than alarm list, and the effect was robust when natural language with spatial information. Therefore, it was necessary to add spatial information. We also considered the subjective index, ranking scores. Consistent with the objective indexes, there was a trend that natural language was better than alarm list, and the effect was more robust when scenarios were presented in natural language with spatial information form.

Many reasons could explain why participants preferred natural language than alarm list. First, there were too many detectors in alarm list. It was hard to remember when the number of detectors was beyond the capacity of human's working memory. Second, participants had to integrate information by themselves when reading alarm list. Third, alarm list was too prolix to comprehend, but natural language was more logical.

There were some problems we did not resolve in this study. Firstly, descriptions of scenarios were presented in text and audio simultaneously, but we cannot control whether they listen to the audio expression. Some participants reported that they were listening not so carefully, information about fire scenario was mainly obtained by reading text. This was maybe one reason for advantage of natural language was not so obviously. Secondly, the quantity of information in these four forms was not equal. Integrated alarm list missed some key information than other forms. Finally, we supposed quantity of traditional alarm list and natural language is equal, but the expression of alarm list is too long, participants had to spend more time to read and listen to this expression. How to control the length of different expression is needed to be discussed in the future.

5 Conclusion

Combined these objective indexes and subjective index together, it suggested that natural language is better than integrated alarm list, especially when fire origin point accompanied with spatial information. Traditional alarm list was more accuracy than other forms, but it cost more time to read and comprehension. For emergency scenes as fire fighting, the expression form which could cost fewer time and bring higher performance will be chose as the final description in real product to improve its quality. So natural language with spatial information will be recommended to be used in the future design of fire alarm system.

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