Mental Workload Assessment Technique for the Navigation System Driver

(자동차 항법장치 운전자의 mental workload 평가에 관한 연구)

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ABSTRACT

This paper suggests the methodology for the ergonomic assessment of the navigation system driver that corresponds to the subjective measurement of the driver's mental workload by rating his or her own driving task. For this approach, Revision of NASA-Task Load Index (RNASA-TLX) was developed which translated and revised the version of NASA-TLX that is generally accepted an efficient and powerful method for evaluating the in-vehicle information system. To verify RNASA-TLX, an experiment was conducted in a real road situation, because the result of the laboratory approach is uncertain and has the differences from the real road test.

1. INTRODUCTION

When the navigation system was introduced into a vehicle, the driver is faced with what Wickens (1980) first referred to as 'resource competition' between the visual demands of the in-vehicle display and the external driving scene[2]. Therefore, most reported evaluations of route guidance or navigation systems have used field trial data, and as such have been limited to attempts to capture a driver's eye glance, in terms of direction, frequency and duration [1]. Those kinds of objective ergonomic assessment parameters for evaluating visual strategies are the important criteria in order to define potential consequences for the disturbance of the driving task, however, they are not the sufficient criteria for assessing the usability and the support of the functions offered by the system and do not give information about the actual driver mental workload [6]. Moreover, human beings are usually very adaptable to the new situations, it is very difficult to analyze the navigation system ergonomic evaluation results by simple stimulus-response types of approaches. However, both subjective and objective methods are complementary, rather than conflict one from another. They are also time and cost consuming and because of the complexity of the driving situations and the inter-individual variability of the driver, it is certainly valuable to have an evaluation process as complete as possible. This paper suggests an RNASA-TLX to implementing the suitable mental workload assessment method for evaluating the navigation system through the real road experiment.

2. EXPERIMENT

All that cases, the navigation system must provide the driver with the simple and compatible information as much as possible for reducing workload and acquiring road safety. This experiment conducted to verify developed the Revision of NASA-TLX (RNASA-TLX) by evaluating the widely used modalities of the navigation system, visual only vs. and visual and auditory combination type. Fourteen male graduate and undergraduate students were recruited. The mean age was 27.7 years old (range = 22 to 32 and deviation =1.3). They had no physical or experience-related problems in driving with 3.1 mean years of driving experience. Two kinds of direction information were presented from a Pentium 90 portable PC equipped with 90W external speaker. That was the static route guidance system type with 2D digital map, however, the communication constraint existed between vehicle and simulator. Therefore, the speed was limited around 40 Km for the driver's safety. An experiment vehicle was driven around the Ajou university and a sample map of target area was conducted for experiment. Firstly, NASA-TLX evaluation session was conducted, however, because of the inappropriateness of the result, the RNASA-TLX was developed and the evaluation session was conducted. For the more accurate results of two sessions, the training session was conducted about the NASA-TLX and RNASA-TLX until they completely understood just before driving. Also, subjects were requested to remember the experiment driving situation and the NASA-TLX, the RNASA-TLX six factors. The tasks took about 15 minutes for each information type. The driving routes of each experiment, had not known to the subjects. During the driving task, visual and auditory information presented before 20m of intersection and the information was maintained until arriving his or her way of intersection - the subjects already knew these conditions before the experiment.

3. DEVELOPMENT OF THE RNASA-TLX

Although there is no universally accepted definition of the mental workload, the basic notion is related to the difference between the amount of resources available within a person and the amount of resources demanded by the task situation. Another well admitted definition considers that the mental workload is the ratio of the task demands to the average of the maximal capacity of each individual. It must be noted that the individual maximal ability is variable. Generally, as task demands increase, so does the mental workload [6]. The purposes of mental workload assessment of the navigation system are as follows.

- Allocating functions and tasks between the driver and the navigation system based on predicted mental workload.
- Comparing alternative component of the navigation system or task designs in terms of the workloads imposed (for example, the modality, the icon, the sound and so on).
- Monitoring the driver of navigation system to adapt the task difficulty or the allocation of function in response to increase and decrease in mental workload.

3.1 NASA-TLX

The NASA-TLX, firstly developed by the U.S. Army, has been used on board samples of people in various situations, and more recently, in the driving environment. After comparison between various existing tools, the NASA-TLX has been considered superior in terms of sensitivity and well accepted by the operator [6][3]. In these days, it is trying to adapt this method for evaluating mental workload of other kinds of in-vehicle information systems, for example, RDS(Radio Data System), CMS(Character Message Sign), ARS(Automatic Response System) etc[1][5][6][9]. Moreover, Shinji Miyake tried to measure the line workers' mental workload through this method [8].

< Table 1 > NASA-TLX

TITLE	DESCRIPTION
Mental demand	How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
Physical demand	How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
Temporal demand	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
Performance	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
Effort	How hard did you have to work (mentally and physically) to accomplish your level of performance?
Frustration level	How insecure, discouraged, irritated, stressed, and annoyed versus secure, gratified, content, relaxed, and complacent did you feel during the task?

This method assumes that the workload is influenced by various factors such as *the mental demand, the physical demand, the temporal demand, the performance, the frustration level* and *the effort*. Table 1 shows the title and the description of the NASA-TLX [3]. These scales were selected from a larger set on the basis of research that showed each scale to make a relatively unique contribution to the subjective impression of workload [7].

3.2 REVISION OF NASA-TLX

The mental workload which is multi-dimensional and it depends upon the type of task. Therefore, the main difficulty for this type of investigation lies in a good understanding of the meanings of suggesting scales. In executing this experiment , despite a detailed explanation and a training session before the experiment, subjects had the problems to understanding and rating the original NASA-TLX six scales. During evaluation session, most of subjects complained that the words that described the scales were so difficult to understand and rate. Because most of scales were consisted of vague, and unfamiliar words for the common driver. Actually, that does not contain any words that are related to the target evaluation system, such as component name, operation-related, and information receiving organ etc. It means that the six scales should reflect the vehicle and the driving situation with driving environment at using the navigation system. Therefore, well defined and clear meanings of words were required to implement this experiment successfully.

To solve this problem, the navigation system interface model and the product analysis were conducted considering the real environment. Through this investigation, all components of the navigation system were examined, could affect on the driver's mental workload.

Finally, through the past and literature study, several problems were identified to implement the NASA-TLX for the mental workload evaluation of driving when using the navigation system by Annie and Anne [6]. As the results, RNASA-TLX six scales were designed with *the mental demand, the visual demand, the auditory demand, the temporal demand, the difficulty in driving* and *the difficulty in understanding information*. In addition to the changed scales, contexts of six scales were also changed more distinctly to minimize the correlation among six scales for better understanding of the subjects and clear results. The procedure was the same with the original NASA-TLX. After assessing the magnitude of each of the six factors on a scale, the individual performs pairwise comparisons among the six scales, in order to determine the higher source of workload factor for each pair. A composite note qualifying the level of workload is developed by using both the scales rating and the relative weights computed from the comparison phase. A weighted workload is so computed for each cited scale and for a global score [5]. Table 1 shows the titles and descriptions of the NASA-TLX and the Table 2 shows the those of the RNASA-TLX.

4. RESULT AND ANALYSIS

RNASA-TLX questionnaires were given just after the completion of the two kinds of experiments. In this version of RNASA-TLX, the scale proposed does not present a graduation so as to avoid over-directing the subjects.

< Table 2 > Revision of NASA-TLX

TITLE	DESCRIPTION
Mental demand	How much mental attention was needed during driving when using the navigation system? Namely, how much mental stress was required during driving via the navigation system : to keep the lane, to avoid the collision, to observe the traffic law, and so other things which related to driving activity.
Visual demand	How much visual activity was required during driving when using the navigation system to recognize the information from the navigation system or other external information sources? For example, digital map and its information and the traffic signal, back mirror, beacon and so other external information sources.
Auditory demand	How much auditory activity was required during driving when using the navigation system to recognize or hear the information presented from the navigation system or other auditory sources?
Temporal demand	How much time pressure was required due to rate or pace at the task elements occurred during driving using the navigation system? For example, in operating or menu selecting process, and information presentation pace or speed.
Difficulty in driving	How hard you driving when using the navigation system with other in-vehicle control equipment or optional devices. For example, car-phone, stick, side break, audio and so on?
Difficulty in understanding information	How hard you understanding information presented from the navigation system? Was the information from the navigation system compatible with your association? Was the mass, density? And other information related factors are suitable for you?

RNASA-TLX that suggested in this paper has three steps of procedures like an original NASA-TLX. Table 2 shows the average weighted workload scores and global score. The visual and auditory combination modality required lower global weighted workload. Looking at the differences of six factors in detail, this modality required higher mental workload only at *the auditory demand.* The visual only type obtained the higher workload in terms of *the mental demand, the visual demand, the temporal demand, the difficulty in driving,* and *the difficulty in understanding information.* The overall weighted mental workloads between two modalities are significant (p=0.05) by Wilcoxon signed-rank test (statistics is W=21 when the sample sizes are 14). Also, as shown in Table 2, the result of the original NASA-TLX was unreasonable as the result of this kind experiment in a common sense. Except *the temporal demand* and *the difficulty in understanding information*, other scales were not significant between two modalities (p=0.05).

<Table 2> The Weighted Workload Scores and Global Score of NASA-TLX and RNASA-TLX

NASA-TLX six scales	Visual	Visual & Auditory	Visual	Visual & Auditory	RNASA-TLX six scales
1. Mental demand	5.29	4.87	14.49	5.34	1. Mental demand
2. Physical demand	5.61	6.69	8.24	6.83	2. Visual demand
3. Temporal demand	9.11	4.41	3.93	12.66	3. Auditory demand
4. Performance	11.09	7.74	25.69	2.70	4. Temporal demand
5. Effort	3.56	5.25	5.47	4.04	5. Difficulty in driving
6. Frustration level	3.56	4.83	5.60	2.40	6. Difficulty in under -standing information
7.Global weighted score	**6.37**	**5.63**	**10.57**	**5.66**	**7. Global weighted score**

5. CONCLUSION

As shown by this experiment, the main difficulty in implementing this method depends on the good understanding of the precise meaning of scales. However, despite the detailed training session of experiment and six scales, original NASA-TLX has a weak point to applying for the specific system like the navigation system. Therefore, if the titles and descriptions of the scales were properly revised, this method will be more powerful to reveal the main mental workload sources. There is one more disadvantage of TLX, despite the convenience of analysis procedure and the derivation of main mental workload sources, this method could not reveal the main factors which influence on each predetermined 6 mental workload source. Moreover, if possible, it is needed to test the reappearance in the time delay. Also, in the pairwise comparison, 9 points scales method was so complex for the subjects to gain the significant results. Through this experiment, it was clarified that the visual and auditory combination information modality required the lower mental workload of the driver when using an IVNS. Also, a problem of this modality was revealed. If the vehicle running the near construction fields or noisy areas, there is a possibility to confuse or misunderstand the information presented form the navigation system. For this reason, most of subjects wanted to auditory options about the characteristics of the voice, age, gender, and tone. Namely, if possible, the navigation system should have the alternative voices to reflect the driver's own ergonomic characteristics and preferences.

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