Evaluation of mental workload accompanying the cognitive task of in-vehicle information devices

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Abstract: The driver's mental workload, constituted of visual cognition, has recently increased with the rapid spread of car navigation systems and other in-vehicle information devices accompanying the progress of Intelligent Transport Systems (ITS). Under such circumstances, accurate evaluation of the driver’s mental workload is important in order to develop in-vehicle information devices that do not jeopardize safety. In this study, an experiment was conducted to evaluate the workload in response to a visual cognition task. The task asked that the subject identify how many characters memorized in advance were contained in a character group shown on a CRT display. In the experiment, mental workload was estimated synthetically from a combination of psychological, behavioral, and physiological viewpoints. When the difficulty of the task increased, the increase in diastolic pressure and beta-1 power ratio of electroencephalogram (EEG) became larger. In conjunction with task execution, parasympathetic nervous activity derived from heart rate variability (HRV) decreased. This result suggests that mental workload could be reflected by several physiological indices such as diastolic blood pressure, EEG beta-1 power ratio, and HRV. In conclusion, it appears that mental workload can be presented to a driver immediately, based on measuring the physiological indices while he or she is actually driving, and safety can be maintained.

Key words: mental workload, working memory, visual search task, EEG, HRV, BP

1. Introduction

In recent years, the rate of mental work accompanying rapid advancements in information technology has increased. Mental work is dispersed throughout our daily lives as the result of computer and information devices such as car-navigation system. Accuracy of evaluation and the measure of physical fatigue on the part of users improve sharply with the development of an objective evaluation index. However, although objective evaluation of mental workload by means of a physiological index has been attempted, no clear valuation basis has yet been found. Moreover, in recent years, methods by which to show a driver's fatigue condition directly has been investigated. Presently, an objective index for use in a technique to evaluate fatigue is desired.

Many physiological techniques designed to evaluate mental workload objectively have been studied. As a physiological index, electroencephalogram (EEG), which is an index of the central nervous system, electrocardiogram (ECG), blood pressure (BP), pulse wave (PW), and blinks, etc., has been respectively used. Rugg and Dickens (1982) reported reduction of the alpha wave of the parietal region during a visual task that involved language and space. The reduction of alpha range during a conceptual composition task has been found (Lang; 1988), and reduction of alpha was also observed during a mental-arithmetic task (Earle and Pikus, 1982). Many reports have shown a decrease of alpha and an increase of beta in response to an increase in the
degree of difficulty of the task.

In this research, while considering the relation among physiological indices, the mental workload in response to visual search work was evaluated. The aim of this investigation was to examine the usefulness of EEG, HRV, and BP as indices of mental workload.

2. Method

2-1. Subject

Subjects were eight healthy university students (8 males, mean age=25 ± 3.2 years). All were right handed.

2-2. Task

The visual search task was conducted on a computer display (Fig. 1). The target character (alphabet) was displayed for 2 seconds on the screen, and then 16 characters arranged 4x4, and one random number from 0 to 4, were displayed. The subject searched to determine how many target characters were present in the arrangement, and judged whether the random number would be in agreement with the number of target characters in the arrangement.

The four task conditions were set to correspond to the number of target characters (condition1=1, condition2=2, condition3=3, condition4=4). The subjective workload score was obtained by using the NASA-TLX. The reaction time (RT) and five physiological parameters (EEG, EOG, ECG, breathing, and BP) were measured. Repeated-measure ANOVAs were carried out, and significant main effects were further investigated by contrast test. The significance level was set at P<0.05.

3. Results and Discussion

Analysis showed a significantly higher reaction time (RT) and higher scores on the six subscales of NASA-TLX with increase in the number of target characters. It was suggested that the number of target characters was carried out different difficulty of short-term memory in present visual search task.

The change in diastolic blood pressure significantly increased as the condition of difficulty increased. This result can be interpreted as due to the fact that the mental demands related to task difficulty correlate to different levels of autonomic nervous activity, which participates in vasoconstriction.

Figure 2. Beta-1 band power change to a different condition

Significant increases of the beta-1 band power ratio of EEG were observed with increase in the number of target characters (Figure 2). Beta-1 band power ratio of EEG was considered to be influenced by the amount of mental load. Although a tendency was observed for LF/HF, which is the index of sympathetic nervous activity, to rise along with task execution, the interaction of conditions and time was significant.
On the other hand, along with task execution, HF/(LF+HF), which is the index of parasympathetic nervous activity, became significantly lower. The interaction of the time and conditions, and the main effect of the conditions, was not significant. From this result, it was suggested that sympathetic nervous activity becomes predominant along with task execution.

4. Conclusions

Precedence research reported that the result, which the visual search task and the operation task resemble most, was obtained. In the present study, the number of target characters of short-term memory influences the difficulty level of the task. Diastolic blood pressure and beta-1 power ratio of EEG are useful in the evaluation of mental workload in terms of ascertaining the degree of difficulty of a visual search task. The influence on mental workload by continuation of visual search work could be evaluated by HRV. In conclusion, it appears that mental workload can be presented to a driver immediately, based on measuring the physiological indices while he or she is actually driving, and safety can be maintained.

References