A STUDY ON THE METHOD OF HUMAN FATIGUE EVALUATION
IN AUTOMOTIVE SEAT

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Abstract: This paper describes a method of human fatigue evaluation in an automotive seat. Until now, an evaluation of an automotive seat has been performed by the expert’s sensory evaluation. Then, to establish a method of human fatigue evaluation objectively, we conducted fatigue experiment for two hours with two seats of different physical characteristics. We consider effectiveness indexes from the experiment and suggest a method of human fatigue evaluation.

Key Words: human fatigue, electromyogram, automotive seat, physiology, evaluation index

1. Introduction

As for the car, needs to the comfort rises with advancement of the safety. In the modern society with much long distance movement, seat development and technology to reduce the human fatigue by long running hours are demanded.

A fatigue degree increases when we sit on an automotive seat for a long time. If physical characteristics of the seat such as a shape or a body pressure distribution etc. change, we predict that the fatigue degree changes. Until now, an evaluation of an automotive seat has been performed by the expert’s sensory evaluation. Therefore the objective evaluation index is not established. So a method that subjective fatigue degree was quantified objectively has been required. In this study, our purpose is to suggest a method of human fatigue objective evaluation in sitting on the seat for a long time in two seats that physical characteristics are different.

2. Experimental Methodology

2.1 Outline

The system used in the experiment is shown in Figure 1. An automotive seat was installed in front of 60-inch screen. We made a subject to be seated and kept them still for two hours. We made the subject concentrate on watching freeway image, which was projected on the rear side of the screen by a projector. While the subject were watching freeway image, we made him to do a task that is to push button when the car in the image had changed lane. In addition, we made him to answer the questionnaire about his fatigue degree every 10 minutes. In this experiment, to evaluate a front passenger seat at static field, the subject was not vibrated and not said to drive.

2.2 Measurement Items

We measured the subject’s electromyogram (EMG) at 8 points of shoulder, back, 4 points in lumbar and 2 points in hip, electrocardiogram (ECG) and perspiration. Before and after experiment, we measured his flicker value and lumbar EMG of the state that lumbar muscle was used voluntarily (called by standard EMG). The subjective quantity was evaluated with questionnaire what consists of 10 stages. We made the subject to answer questionnaire.
orally before the experiment and every 10 minutes during the experiment for two hours. The number of subjects is eight in the experiment.

2.3 Automotive Seats
The characteristics of two seats that we used for the experiment are shown below.
seat1 - Conventional urethane seat.
seat2 - Three-dimensional knitting seat which elasticity is near to a human muscle.

3. Result of Experiment
3.1 Subjective Quantity
Subjective quantities of fatigue are shown in Figure2. The values are the average of all subjects in each seat.

We conducted statistical analysis (T-test) to verify difference between the seats. In subjective quantity of fatigue, a significant difference was verified in 20 minutes. But there were no significant differences in other times. In the seat2, the standard deviation was small until the middle stage of the experiment. From the result, we found that all subjects were felt fatigue degree similarly in the seat2. Also it followed that the seat2 was dominant at the shoulder in 30, 40 and 60 minutes, at back in 50, 60 and 80 minutes, at lumbar in 20 minutes. About the evaluation value at the last stage, there were no differences. But until the middle stage of the experiment, we think that the seat material effects subjective quantity.

3.2 Standard EMG Analysis
Figure3 shows the change ratio of the amplitude of a standard EMG (SEMG) in each seat. The change ratio is a ratio of values of after and before the experiment. The value is the average of all subjects.

In Figure3, the SEMG amplitude decreased in almost all regions at all subjects. An increase of EMG amplitude by muscle fatigue generally said did not occur. It is said that an increase of EMG amplitude by muscle fatigue is set up by the work of the neighboring muscle fiber of the tired muscle fiber. The reason of the decrease of EMG amplitude in this experiment is why the muscle fiber other than the region that we measured took activity. In the subjective quantity, pain of his back in the seat1 and pain of his lumbar in the seat2 are bigger than those of the other. In the change ratio of SEMG amplitude, we verified that there are differences for the change by the difference of the part that is near to the back and lumbar. Therefore, we decided that the rate of the decrease of the broadest muscle of back1, 2 and the erector muscle of spine1 near his back can be an evaluation index of pain of the back. And the rate of the decrease in the other muscles can be one of pain of the lumbar.

3.3 EMG Analysis
Generally, when muscle gets tired, it is known that EMG amplitude and the low frequency component in frequency distribution increases. Even as for this study, we paid attention to these two points and analyzed them.

3.3.1 Evaluation of EMG amplitude
Figure4, 5 and 6 show the change of the average EMG amplitude value every 10 minutes of the subjects expecting two
subjects in an error. They are normalized with the value of the experiment for point 10 minutes.

In Figure 4, as for seat 1, the value varies widely, but the time of the point increase of the EMG was earlier than that of the seat 2. In Figure 6, as for the seat 2, the time of the point increase of the EMG was earlier than that of the seat 1. These tendencies were the same as the subjective quantity. In addition, we checked the point to vary widely in EMG amplitude effected subjective quantity from Figure 5. Therefore, we decided that the increase and the decrease of EMG amplitude can be the evaluation indexes of the fatigue.

3.3.2 Evaluation of Frequency

We conducted frequency analysis and applied for spectrum distribution. As a result, we applied for variation of area ratio of 0-100Hz for 0-30Hz, considering that there is peak frequency in the vicinity of about 20Hz. Figure 7, 8 and 9 show variation of area in 10-30Hz for 0-100Hz that is normalized with the value of point 10 minutes.

In Figure 7, the area ratio tends to decrease, especially in the seat 1, the tendency is strong. In Figure 9, especially in the seat 2, the tendency is strong in the last stage. In Figure 8, there is significant difference between the seats in about 50 minutes when the decrease is big. The size of these increases and decreases is agreed with the subjective quantity. Therefore, we decided that the decrease of the area ratio of 10-30Hz can be an evaluation index of the
fatigue.

3.4 ECG Analysis
We conducted frequency analysis from RRI-curve that is provided from the ECG. We calculated the area of low frequency (LF) in the range of 0.07-0.015Hz and high frequency (HF) in the range of 0.15-0.45Hz. HF/(LF+HF) is an index that reflects parasympathetic nerve activity. We examined the tendency. Figure10 show variation of HF/(LF+HF) that is normalized with the value of the point 10 minutes.

![Figure 10 Variation of HF/(LF+HF)](image)

The value in the early stage of the experiment tends to decrease, but the value in the middle stage tends to increase. The value in the last stage tends to decrease again. The relation coefficient of HF/(LF+HF) value is about 0.7. Although ECG is an index by which the mental burden is evaluated, the relation coefficient of the stress and the fatigue was very high in the experiment. Therefore, we decided that the value can be the evaluation index of the fatigue and the mental burden.

3.5 Perspiration Analysis
Mental perspiration is urged by stress and strain. The increase of the value shows mental burden. Figure11 shows perspiration ratio normalized with the value of the point 10 minutes.

![Figure 11 Variation of perspiration](image)

In the seat1, the value varies widely. But in seat2, the value was almost constant. The relation coefficient with the discomfort of subjective quantity is about 0.6. In addition, there is significant difference in about 60 minutes when the variation is big in the seat1. In the experiment, the relation coefficient of the discomfort and the fatigue was very high. Therefore, we decided that perspiration ratio can be the evaluation index of the fatigue and the discomfort.

4. Conclusion
In the experiment of sitting on the seat for two hours in two different seats with physical characteristics, we concluded the following things.
1. The difference of the seat material affects subjective quantity until about 80 minutes.
2. In standard EMG, fatigue degree of back and lumbar are evaluated with the decrease of rate of EMG amplitude.
3. Muscle fatigue is evaluated with the decrease of the area ratio of 10-30Hz for 0-100Hz.
4. The fatigue, the mental burden and the discomfort are estimated from HF/(LF+HF) and perspiration ratio.

Reference