1. Introduction

In recent years, various human support systems have been developing. Then, we think that it is necessary to investigate a transition of the psychosomatic state. Because, when developing a suitable supporting system, we think that it is necessary to take into consideration the influence of human's psychosomatic state. There are some researches who reported the psychosomatic state when driving the vehicle. First, regarding the measuring of the psychosomatic state, Fujita and others have developed a method of fatigue evaluation when sitting down [1]. Next, regarding the research which analyzed the psychosomatic state and evaluated the system, Suzuki and others investigated the influence of the psychosomatic state on a driver when fragrance is supplied. And they showed that Alpha Pinene was effective in reducing a feeling of fatigue [2].

We proposed a changing state hypothesis [3]. It classifies human's psychosomatic state into four terms. This state of human body is always going back and forth among these four states. This psychosomatic state will be various based on the individual characteristics such as the preference of each operator. For example, while an operator uses a support system, the activation level of sympathetic nerve becomes predominant. Therefore, it is important to estimate the psychosomatic state in consideration of individual characteristics because each operator has own state transition of “the changing four term state hypothesis”. On the other hands, the psychosomatic state changes under the external stimuli like olfactory stimulus or acoustic stimulus. These external stimuli can be utilized for the human machine interface of support system. For example, it was reported that the sonic system mounted on a car or a train enables to minimize the drowsiness of operator and the super-sonic system can minimize the mental stress. We think that if it becomes possible to estimate the psychosomatic state of human, we can provide the suitable human support system that corresponds to the change of psychosomatic state. In this research, we investigated the transition of psychosomatic state under presenting olfactory stimulus, auditory stimulus and mental workload. Finally, we analyzed the relation between the psychosomatic state transition and individual characteristics.

Keywords: Psychosomatic State, Individual Characteristic, Olfactory Stimulus, Auditory Stimulus
relaxation. Similarly, the horizontal axis of the state transition hypothesis utilized the homeostatic function. If the value of this function increased, the mental state is easy to recover from the fatigue. And if the value of this function decreased, the state shows that driver's fatigue is increased. From the above, four states classified according to two axes are explained. The state #I means the large fatigue. Since it is in the state which sleepiness and micro-sleep tends to generate, the state of a human is "Sleepiness term". The state #II means the little fatigue. Since it is in the state where concentration is increasing, the state of a human is "Concentration term". The state #III means the little fatigue. Since it is a relaxed state, the state of a human is "Rest term". The state #IV means the large fatigue. Since it is in an aimless state, the state of a human is "Aimless term".

2. Physiological Index

2.1 Electrocardiogram

2.1.1 RRI

The interval of R waves (RRI: R-R interval) is picked out from the wave of an electrocardiogram (ECG). It is possible to evaluate the activity level of autonomic nerve system from the time series data of changing RRI. In this research, RRI was averaged by the time window for 180 seconds.

2.1.2 LF/HF of RRI

The LF/HF (LF: Low Frequency, HF: High Frequency) obtained by conducting frequency analysis as one of the major analysis methods of RRI. The power value of LF reflects the activity level of both the sympathetic nerve and the parasympathetic nerve. HF reflects the activity of the parasympathetic nerve. In addition, LF/HF and LF/(HF+LF) are calculated from the area of the power spectrum of LF ingredient (0.04~0.15 Hz) and HF ingredient (0.15~0.4Hz). If the value is large, it can be said that the sympathetic nerve activity is increasing relatively.

At first, we measured RRI in software made by ADInstruments Pty Ltd. Next, time series data are again sampled at the frequency of 1 Hz. We performed wavelet transformation and calculated LF and HF.

2.2 Pulse Wave (Finger Pletysmogram)

The pulse wave was investigated by using the instruments made by CCI Co., Ltd. A measurement machine consists of an infrared light emitting diode and photograft transistor (Figure 2).

The infrared rays with a wavelength of 940-mm are projected from an infrared light emitting diode. The infrared light is reflected in a finger. The capacity change of an artery is detected by entering in a photograft transistor the catoptric light. The analysis of pulse wave is based on a method which Fujita and others proposed [4].

2.3 Method of calculating the plot points

As a method of plotting on the four term state hypothesis, we used the analysis results of standardization process the biological index. The methods of standardization are shown below.

\[ x = \frac{1}{n} \sum_{i=1}^{n} x_i \] ................................. (1)

\[ s = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2} \] ................................. (2)

\[ z_i = \frac{x_i - \bar{x}}{s} \]

\[ z_1 = \frac{x_1 - \bar{x}}{s}, z_2 = \frac{x_2 - \bar{x}}{s}, \ldots, z_n = \frac{x_n - \bar{x}}{s} \] ................................. (3)

\[ X_\alpha = \frac{1}{\alpha} \left( \sum_{i=1}^{n} Z_i \right) \] ................................. (4)

\[ Y_\alpha = \frac{1}{\alpha} \left( \sum_{i=1}^{n} Z_i \right) \] ................................. (5)

The calculation of the value on horizontal axis used the power gradient of pulse wave. When this value is high, the fatigue level is accumulated easily. And, the calculation of the value on vertical axis used the value of LF/HF. If this value is high, the sympathetic nerve is predominant. At first, we calculated the average of all data using equation (1). Next, we calculated the standard deviation of all data using equation (2). In addition, we calculated z-score using equation (3). Finally, using equation (4) and (5), the average of 180 seconds was calculated for every 90 seconds. From these calculations, we plot the time series change of LF/HF and the power gradient of pulse wave.

3. Estimation of the threshold

We carried out experiments to determine the four terms changing state hypothesis. The investigation items are the subjective evaluation, and the physiological index which are mentioned above. Before carrying out the main investigation, the quiet condition was set up for 3 minutes in order to stabilize a psychosomatic state. The main investigation was set up for 7 minutes. During
investigation, the experiment subjects performed Uchida Kraepelin psychodiagnostic test [5]. This test is a task which continues numerical addition. The experiment subjects are five male college students (subject #A~#E).

The result about the state transition of subject #A is shown in Figure 3. When it changes from a quiet condition to a workload condition, LF/HF is increasing. On the other hand, the power gradient of pulse wave is decreasing. The results of all subjects showed the same tendency. Therefore, when it changed from a quiet condition to a workload condition, it was shown that the psychosomatic state is changing from “State IV” to “State II” of the four term state hypothesis. And we clarified that there was a significant difference in each change by the quiet condition and a workload condition as shown in Figure 4. Then, we analyzed the threshold value using the result of a quiet condition. In a calculation of the threshold value, we used the average value and standard deviation of LF/HF or the power gradient of pulse wave. As a result, we obtained the threshold value [1.0, -0.3].

4. The influence investigation by external stimuli

4.1 Auditory stimulus

The experimental condition like the test subjects and the investigation items are same as the estimation experiment of the threshold. In this experiment, we provided the subject with a 31.5 Hz (1/3 octave band) low-frequency auditory stimulus during the experiment.

The results regarding the changing state hypothesis of subject #C is shown in Figure 5. The value of LF/HF in a quiet condition is high. In addition, the change of psychosomatic state has restrained in the range of the “State II” at workload condition. Therefore, it can be conjectured that the auditory stimulus of low frequency has influenced on the autonomic nerve system and retained the concentration state “State II”. For example, regarding the driving behavior of a vehicle, it is expected that a low frequency wave like the engine sound influences on driving behavior. It is the effect of keeping concentration state, without increasing a stress and fatigue.

4.2 Olfactory stimulus

The investigation items are same as the estimation experiment of the threshold. Before carrying out the main investigation, the quiet condition was set up for 5 minutes in order to stabilize a psychosomatic state. The main investigation was set up for 20 minutes. During the investigation, the experiment subjects performed Uchida Kraepelin psychodiagnostic test. The next step is to supply the fragrance of Limonene for ten minutes after the main experiment. We supplied the fragrance of
Limonene to experiment subjects using a cannula. The experiment subjects are nine male college students (subject #A~#I). All subjects prefer the fragrance of Limonene.

The results regarding the changing state hypothesis of subject is shown in Figure 6. We analyzed the change in the four term state hypothesis. After supplying the fragrance, subject #A and #I was shifted to the rest term “State III”. On the other hand, subject #F and #G resulted in shifting to the concentration state “State II”. And, there was no effect of the fragrance.

![Graphs showing state transitions](Image)

**Fig 6. Influence by the fragrance on the state transition (Subject #A, #I, #F and #G)**

In the experiment of fragrance presentation, it turned out that the workload brought by the sub task was different among subjects. Although the transition of autonomic nerves was not changed by the workload brought by the sub task, there was a subject whose fatigue level was increased. On the other hand, although there was no transition of fatigue, there was a subject whose sympathetic nerve became predominant. From this result, it turned out that the effects by receiving the load was various. And, we considered that individual characteristics affected the effect of fragrance presentation. We classified the characteristics of its transition visually using the four term state hypothesis.

At first, there was a subject who received workload through the increase of autonomic nerves. The fatigue was not increased but the transition of autonomic nerves occurred. Secondly, there was a subject who received workload through the increase of fatigue. Although the activation level of autonomic nerves was not change, a fatigue level was increased. Thirdly, there was a subject who received workload through the increase of autonomic nerves and fatigue. These subjects had a pattern that the fatigue level was increased while relaxing, and a pattern that the fatigue level was increased while relaxing. We think that the preference of a sub task had influenced on the psychosomatic state.

Therefore, it was suggested that the four term state hypothesis can be used also as an index which can judge individual receptivity.

### 6. Conclusion

We investigated the change of psychosomatic state under presenting auditory stimulus and olfactory stimulus.

We explained the effect of low frequency sound on using the four term state hypotheses. We also found that the low frequency sound influenced on the fluctuation of autonomic nerves, and on keeping concentration state. In addition, in the experiment of fragrance presentation, it turned out that the effect of fragrance was different among subjects. We thought these differences were caused by the individual receptivity of task. And, we suggested that we can classify the individual characteristics of its transition visually using the four term state hypothesis. In the future study, we will increase the number of subjects and will clarify the mechanism regarding the influence of an external stimulus on psychosomatic state. We will continue to investigate the optimal support corresponding to each state.

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