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Detection of Temporary Rest State when Performing Intelligent Works by Measuring Physiological Indices

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In order to evaluate intellectual productivity caused by the work environmental change, subject experiments have been conducted in the conventional studies where specially designed tasks were given and the task performance were measured. However, the result may not be reflected the actual intellectual productivity because the designed tasks are different from the actual office work. It is said that there are two mental states (work and temporary rest state) in office workers which are changing alternatively during intellectual work and the ratio of the two states reflects the productivity. If the mental states of the workers can be detected somehow, the productivity can be measured more accurately by their daily works. In this study, therefore, the authors have aimed at developing a detection algorithm of work/non-work state (temporary rest state) by measuring physiological indices such as EEG, HR and EMG aroud left eye. As the result, the mean accuracy of the develped algorithm is 64.1% which is 18.7% higer than that of random guessing ($p<0.01$).

Detection of Temporary Rest State when Performing Intelligent Works by Measuring of Physiological Indices

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Abstract: In this study, an algorithm to detect temporary rest state when performing intelligent works by measuring of physiological indices has been developed. As the result of the experiment, the detecting performance was found 18.7% higher ($p<0.01$) than random detection rate. This result shows the possibility to use the physiological indices as one of the mental state detection methods.

Keywords: Intellectual productivity, Measuring of physiological indices

1. Introduction

Recently, intelligent works have occupied most of office works in companies and have become more and more valuable in our society. Therefore economic and social benefits can be getting larger by improving intellectual productivity such as efficiency and accuracy of intelligent works. In order to achieve this, the objective evaluation method of intellectual productivity is required, and many studies have been conducted. Obayashi et al. have developed specially designed tasks for quantitative evaluation of intellectual productivity[1)]. However, many tasks used in experiments for the evaluation are different from actual office works, because the tasks have been designed in order for experimenters to collect task logs easily and accurately. In order to evaluate intellectual productivity in actual office, it is desired to use actual office works. It is however difficult to collect and evaluate most of their logs. On the other hand, Kawano et al.[2)] have revealed that there are two mental states (work state/non-work state) in the office workers which are changing alternatively during intelligent work and the period when workers are resting can be calculated by the ratio between these two states, and intellectual productivity can be evaluated quantitatively. In this study, therefore, the authors have aimed at developing a detection method of work/non-work states by measuring physiological indices. Concretely, electrocardiogram (ECG), electromyogram (EMG) around left eye and electroencephalogram (EEG) were measured as the physiological indices. And high and low frequency wave of heart rate, eye blink rate, saccade eye movement rate, alpha and beta wave of EEG were extracted as feature values. Based on these feature values, an algorithm to detect temporary rest state (non working state) has been developed. If this algorithm is developed, intellectual productivity in office works can be evaluated quantatively because this algorithm requires only physiological indices of mental workers, not specially designed tasks. Therefore it is expected that intellectual productivity can be evaluated more accurately in offices by using this algorithm.

2. Method

2.1 Participants and measurement

26 healthy volunteers participated in this experiment who are the ages of 19 to 25 and could operate PC without difficulty and their native language was Japanese. The experimental period was approximately 2 hours. The subjects were instructed to conduct mental tasks and their physiological indices were measured. And based on these indices, their two mental states (work and temporary rest state) have been detected. The temperature, illuminance, and ambient noise of the experimental room were controlled to 25±1℃, 680lx ,and 50±3db respectively. In this experiment, the subjects equipped the instruments measuring physiolocal indices, and their ECG, EMG around left eye, EEG have been measured. EEG electrodes were placed on Pz, Cz and Fz according to the international 10-20 system and their midline electrode was placed on left earlobe. ECG electrodes were placed on the left side of the body and the right side of the neck. EMG electrodes were placed on the left temple and upper part of the left eye blow. The position of these electrodes is shown in Fig. 1.

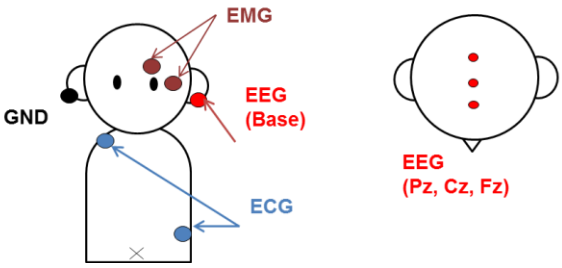

Fig. 1: Locations of electrodes.

2.2 Experimental design

The experiment consisted of 2 measurements which were the measurement for training data and for test data. The subjects performed tasks in three conditions which were task, control and rest condition. In this study, these three conditions were difined as follows: In the task condition the subjects perform one of the given tasks, and in the control condition they move their arms and fingers as the same way as the task without thinking, and in the rest condition they do not move or think. In this experiment, they were instructed to perform these actions in each condition, and specially in the rest condition they were instructed to stop moving and gaze a black fixation cross without thinking. In the measurement for training data, these three conditions were changed in turn by switching a presented display automatically every 30 seconds as shown in Fig. 2. Tasks, figures (such as a square, a triangle and a circle) and a black fixation cross were presented in the task, control and rest condition respectively. In each condition, the display was presented for 30 seconds and these procedures were repeated 5 times. In the measurement for test data, the subjects were instructed to perform tasks for 7.5 minutes by switching these three conditions freely. In order to confirm the dependence of this algorithm's performance on tasks, 5 types of tasks were employed.

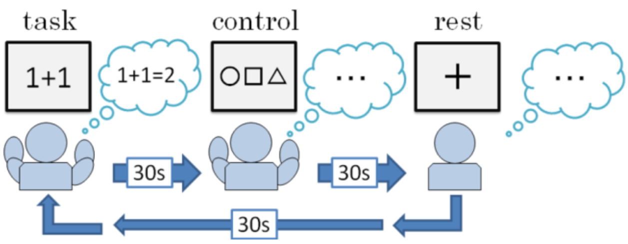

Fig. 2: The sequence of task in the training data measurement.

2.3 Tasks

5 types of tasks were used such as 1-digit addition, 3-digit addition, classification, block assembling, text typing in the experiment. In the case of 1-digit addition, the subjects were instructed to add two 1-digit integers presented on a PC display, and type the answer in the PC. In the case of 3-digit addition, they were instructed to remember one 3-digit integer and press the enter key. Then another 3-digit integer was presented and they were instructed to add these two 3-digit integers and type the answer in the PC. In the case of text typing, they were instructed to type sentences presented on a PC display with a keyboard. In the case of classification, they were instructed to look at the amount, date, name of a company in a receipt shown in Fig. 3 and classify it by tapping the classification table on iPad display as shown in Fig. 4. In the case of block assembling, they were instructed to freely assemble blocks presented on a PC display and name a assembled figure as shown in Fig. 5.

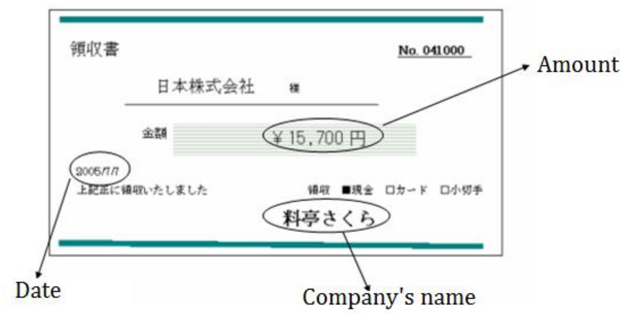

Fig. 3: An example of receipts in classification task.

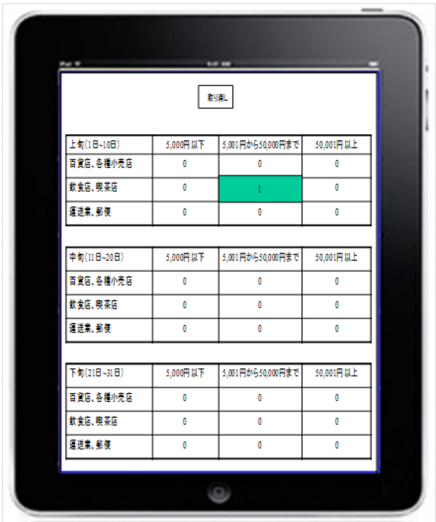

Fig. 4: The classification table on iPad display.

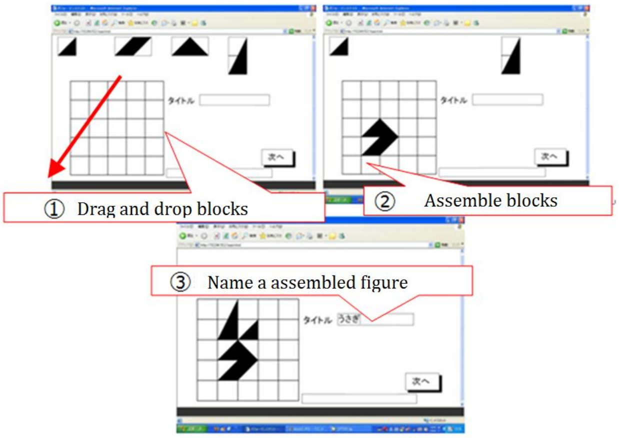

Fig. 5: Block assembling task.

2.4 Data Analysis

First, feature values were extracted every 2 seconds from the physiological indices measured as training data and the classifier for a linear discriminant analysis (LDA) was calculated from these feature values. Then the LDA classifier has been applied to the feature values extracted every 2 seconds from test data and detected the subject's present condition (one of the task, control ,and rest condition). After the detection, the task condition has been regarded as "work state", and the control and the rest condition have been regarded as "temporary rest state" as shown in Fig. 6.

In order to evaluate the performance of the developed algorithm, the actual mental states (work or temporary rest state) were detected by task logs and compared with the mental states clasiffied by this algorithm. Then the performance of the algorithm was evaluated by the ratio of correctly classification by the algorithm.

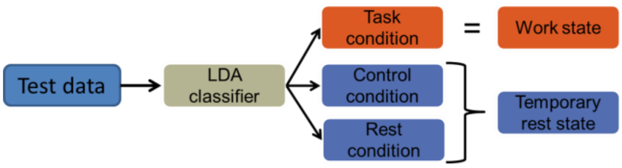

Fig 6: The method of detecting two states

The method of extracting feature values from physiological indices is described below.

In the analysis of EEG, brain waves of EEG at Fz and Cz were excluded from this analysis because EMG caused by eye blinking affected the brain waves as artifact. And alpha (8 to 13 Hz) and beta (13 to 30Hz) wave at Pz were calculated as feature values every 2 seconds by the Fourier transform.

In the analysis of ECG, the high (0.20 to 0.35 Hz) and low (0.05 to 0.20 Hz) frequency wave of heart rate were calculated as feature values every 2 seconds. In order to calculate these feature values, the Gabor Wavelet transform[3)4)] have been applied among various types of frequency analysis methods because 2 second time window was too short to apply other frequency analysis method. The concrete transform equation is described below;

$$WT(b,a) = \frac{1}{\sqrt{|a|}} \int_{-\infty}^{\infty} f(t) \overline{\psi(\frac{t-b}{a})} dt \qquad (1)$$

$$\psi(t) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\frac{t^2}{2\sigma^2} - i2\pi t} \qquad (2)$$

In the analysis of EMG around left eye, eye blink rate and saccade eye movement rate were calculated as feature values every 2 seconds.

3. Result

R waves of ECG of 5 subjects could not be detected properly or the amplitude of these waves have been found too small, so that the measured data of these subjects were excluded from the analysis. And there were 2 cases where a task could not be performed for a fault of experimental PC, so that the measured data when the fault occurred were also excluded.

Table 1 shows the detection accuracies of this algorithm and that of random guessing. Every accuracies of random guessing are not 50% for the following reason; If each of 3 conditions is detected at random (with a probability of approximately 33%), the probabilities that work and temporary rest state detection are approximately 33% and 67% respectively. However in the measurement for test data, the ratio between 3 conditions depended on the subjects and tasks because the subjects performed every tasks by switching these conditions freely. Therefore, the accuracies of random guessing are different depending on the subjects and tasks.

Table 1: Accuracies of this algorithm and random guessing in each task

Task	n	Accuracy			
		this algorithm		random guessing	
		Mean(%)	SD	Mean(%)	SD
1-digit addition	21	64.6**	17.0	44.2	3.82
3-digit addition	21	65.5**	12.5	46.4	5.13
Classification	21	66.5**	11.3	48.4	5.73
Block assembling	20	63.1**	10.9	43.9	4.70
Text typing	20	60.5**	14.5	44.0	4.15

As the result, the accuracies of this algorithm is significantly higher than that of the random guessing in each task based on Welch-Test ($p<0.01$). And the mean accuracies of this algorithm and the random guessing in all the tasks is 64.1% and 45.4% respectively, and that of this algorithm is 18.7% higher than that of the random guessing ($p<0.01$).

4. Discussion

In this study, the detection algorithm of temporary rest state when performing intelligent works was developed and it was found that the accuracy of this algorithm is significantly higher than that of the random guessing ($p<0.01$). Then based on analysis of variance, the mean accuracies of this algorithm in each task is not significantly different ($F(4,98)=2.47$, $p=0.676$). This suggests that the algorithm may be independent on 5 tasks used in this study. However, these tasks were specially designed in order for experimenters to collect the task logs and to evaluate the accuracy of this algorithm. And in order to evaluate intellectual productivity in offices, it is necessary to use actual office works as the task. Therefore it is required to confirm whether this algorithm can be applied to not only other tasks but also actual office works. This study have used the physiological indices such as EEG, ECG and EMG around left eye, but others such as electrodermogram (EDG), cerebral blood flow (CBF) has a possibility to reflect two mental states (work and temporary rest state). Therefore other physiological indices should be considered in order to establish more accurate detection method.

The mean accuracy of this algorithm is 64.1% and it is not enough. The algorithm, however, have suggested the possibility that work and temporary rest state in office workers can be detected based on physiological indices. In the future, the authors will aim at improving the accuracy of this algorithm by trying various physiological indices. If this becomes higher enough, it is expected to evaluate intellectual productivity in office works more accurately.

5. Conclusion

There are two mental states (work and temporary rest state) in office workers which are changing alternatively during intelligent work. In this study, the authors have aimed at developing the detection algorithm of these states by measuring physiological indices. The mean accuracy of this algorithm is 64.1% and 18.7% higher than that of random guessing ($p<0.01$). This have suggested the possibility that physiological indices could be used to evaluate intellectual productivity. However, because the accuracy is not enough, it is necessary to consider other physiological indices and detection methods to improve the detection accuracy. If the algorithm is improved to the point where the mental states could be accurately detected, the intellectual productivity of office workers can be evaluated more accurately.

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