Proposal of an Office Work Productivity Model Based on Short Pauses in Mental Tasks

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Abstract. In this study, the authors propose a model which can explain and simulate the change of office work productivity. This model assumes office workers transit a working state and a non-working state with the probabilistic functions based on the variation of brain fatigue. Aiming to discuss the detail of the model, the authors have conducted a subject experiment in which work motivation are controlled. Comparing the results of the experimental results with the result of computer simulation based on the model, it was found that the subjects tend to concentrate the task when the remuneration is provided, and they try to keep their attention to the task and take a long break instead when the task workload is high.

Keywords: Productivity, Working State, Probabilistic Functions, Human Modeling.

1 Introduction

Recently, many office building have been trying energy saving to reduce CO2. Cool Biz, the activity wearing casual style clothes and setting air conditioners at 28 degrees in the summer, is a major activity in Japan. However, we should consider not only wattage per hour but also comfort of office. Recent studies have revealed that improvement of office environment may improve the productivity of office workers [1]. If the office condition takes working time long, there is a risk of increasing total energy consumption.

The authors, therefore, had developed an office work performance test, CPTOP (Cognitive Performance Test for Office Productivity), aiming at establishing an evaluation method of office work productivity [2]. In addition, the authors proposed a circadian lighting system, which promote productivity by adjusting circadian rhythm with high luminance light, and conducted laboratory experiments with CPTOP. As the experimental result, it was found that the results of both CPTOP and simulated office work under the circadian rhythm lighting were improved approximately 4% comparing with the normal lighting [3].

As a result of many studies aiming to reveal relationship of productivity and indoor environment (ventilation, temperature, noise, etc.), the environment which promotes office work productivity becomes elucidated.

However, the mechanism of its change is unexplained and the size of it also depends on tasks and human internal factors. Therefore, the author is trying to create

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a model which can explain and simulate the change of office work productivity. In this study, as the first step of creating model, the authors have conducted a subject experiment focusing on internal factors. In this experiment, the indoor environment was fixed. Because, the effect size of motivating factor is larger than indoor environment. The motivating factor is suitable for considering about the process of productivity change.

With the experiment result, authors discussed the details of the model by comparing the results of the computer simulation based on the model with the experimental results. If this model is completed by the result of experiment, which the authors are planning to conduct for revealing the effect of indoor environment, we can predict productivity without experiment, and optimize the balance between productivity and energy use by the model.

2 Proposal of the Model

2.1 Target Extent of the Model

There are much type of office work and factors which affect productivity. These factors also affect each other. Because of its complex relationship, it is difficult to make a model considering all factors. In this study, authors limit target extent of the model.

2.2 Factors

Indoor environments are one of the factors which affect work place productivity, and many studies are focusing on them. However, their affect is not only physiological but also psychological. In addition the size of productivity change caused by them is small and its size variable. On the other hand, it is quite unlikely to human inner factors, like motivation, change indoor environments, and their effect size is large. In this study, the proposing model is aiming to explain the process of productivity change. And the type of factor which causes productivity change is not important. In this study, we focus inner factors, especially motivation and mental workload.

2.3 Contents of the Work

There are various kinds of office works, and the human abilities for office work also various. But, works which occupy a considerable amount of working time are mental tasks which have standard routine, for example, paperwork or information processing. These mental tasks which use conscious symbol processing can be explained using with analogy of work of single processor computer. Using this analogy makes it easy for modeling the process of office work and to simulate the office works on computers. Computer simulation would be useful for predict productivity change. Because of it, the type of office work in the model is using conscious symbol processing. On the other hand, the model doesn't consider about more complex tasks, which need advanced creative abilities.

2.4 Working Style

The working style in real office is seem that office workers devote a given time period for their work. The period would be more than 30 minute or several hours. And workers address their works at their own pace In this period. In this study, working style are assumed as above one.

2.5 Time-Series Analysis of Previous Experiment

Aiming to guess the mechanism of work productivity change, the feature of an experimental result was extracted with time series charts. This experiment conducted in 2008[4] was aiming to compare task performance under bad environment (30 degrees, 750lx) with good one (26 degrees, 2500lx). As a result, the performance of receipt checking task in good environment was higher than one in bad. In receipt checking task, there are many 200 paper receipts and the information (Amount of money, Date, *etc*…) corresponding receipts are shown in PC screen. Subjects should check the information error in seven teen minutes.

Figure 1 is one of the experiment results. The axis of ordinate shows the times of checking one receipt. Abscissa axis shows the lapsed time. As shown in fig 1, the mid-level time of checking receipt looks similar in both environments. On the other hand, the numbers of sheets for which the subject took more than twice time longer than mid-level time looks similar in both environments. The numbers clearly looks higher in bad environment than good environment. A receipt checking task is simple task and the time for checking is almost same in every receipt. It means that the time subject takes long for checking is shouldn't be for only checking but including short time pause. For this reason, the authors assumed that the main process of productivity change is these pauses and this pauses play a role of relieving fatigue.

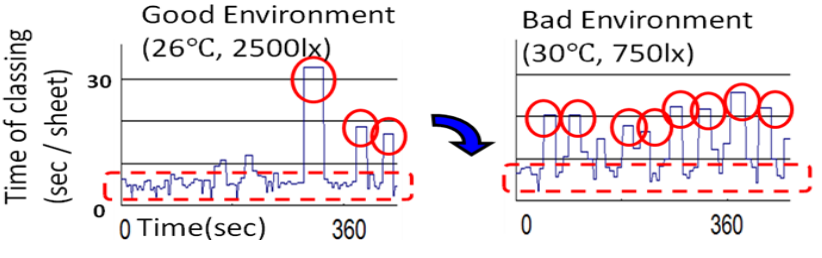

Fig. 1. Time series analysis of previous experimental result

2.6 Framework of the Model

From above analyzing, the authors propose an office work productivity model based on short pause. Figure 2 shows the framework of this model.

1. Office workers are assumed to transit a working state and a non-working state.
2. The transition of these two states is along with the probabilistic functions based on the variation of BF. BF is a hypothetical value which is assumed as a brain fatigure.
3. Office workers are assumed to transit these two states along with the probabilistic functions based on the variation of BF.
4. At working state, the working progress goes off and value of BF increase. On the other hand, at working state, working progress stops and value of BF decrease.
5. The transition probability is determined by human inner factors, indoor environment and so on.

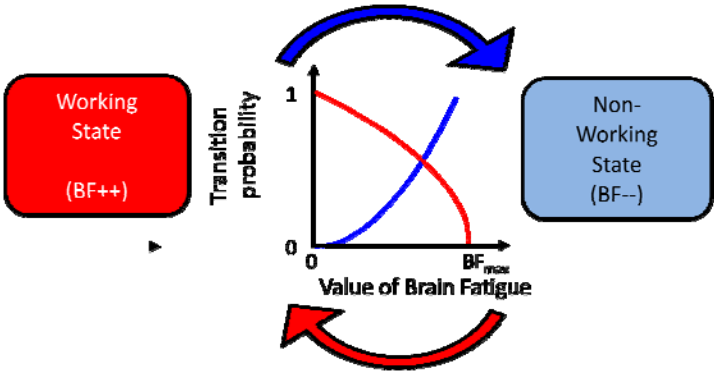

Fig. 2. Framework of the model

2.7 Computer Simulation Based on the Model

This model is created with an analogy of computer and can simulate the change of working state and productivity. Concretely, if two transition probability,$P_1(BF)$ means from working to non-working, $P_2(BF)$ is from non-working to working, and the change speed of BF is determined, model simulate how the works progress and simulate productivity with probability. In this study, the authors used equation (1) to (3) as transition probability and change speed of BF. These equations are determined aiming to explain the change of equations with few parameters.

Parameter a_1 and a_2 means the tendency to transit. If these parameters become higher, the probability becomes higher at same value of BF. Parameter v_1 and v_2 means the change speed of BF.

$$P_1(BF) = \left(\frac{BF}{BF_{max}}\right)^{a_1} \quad \text{(working to non-working)} \qquad \cdots(1)$$

$$P_2(BF) = \left(\frac{1-BF}{BF_{max}}\right)^{a_2} \quad \text{(non-working to working)} \qquad \cdots(2)$$

$$\frac{dBF}{dt} = \begin{cases} v_1 - v_2 \cdot BF \text{ (wroking state)} \\ v_2 \cdot BF \text{ (non working state)} \end{cases} \qquad \cdots(3)$$

3 Subjective Experiment Controlling Inner Factors

3.1 Purpose

The experiment in 2.2 had problem that the number of subject is few and the experimental condition was complex. The purpose of this subjective experiment was collecting the time-line data of working under motivation and mental work load was controlled. In addition, by comparing experiment result and simulation result based on the model, the model parameter derived on each condition and discuss about this model.

3.2 Experimental Method

In this experiment, the task performance was measured in two motivational conditions and in two mental work load condition and compared. This experiment was conducted on Nov 24 to 29 in 2009. Figure 3 shows a scene of experiment. During this experiment, the environment was fixed. The illumination on the desk was 750lux, temperature was 25 degrees, CO2 concentration was under 800ppm and noise level was under 52dB. Twelve subjects joined this experiment, who are seven males and five females. The average age was 21.7.

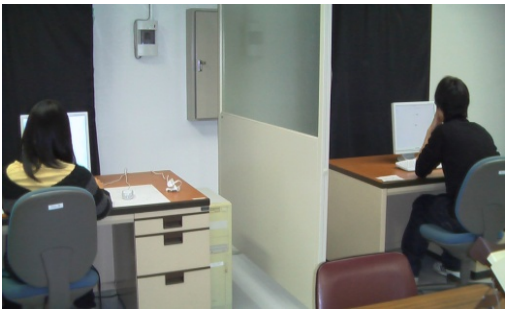

Fig. 3. a scene of experiment

Controlling inner factors. In this experiment, motivation to the work was controlled. In "high motivated" condition, the subject was explained that they could get additional payment according to their task performance. In "low motivated" condition, there was no additional payment. The motivation was checked with a subjective assessment index. In addition, the mental load work to the work was controlled to two conditions by task difficulty. The mental work load was checked with NASA-TLX [XX].

Task. The task used in this experiment was mental addition task. As shown in Figure 4, the first numbers is displayed in window, and when enter key was pressed the second number is displayed. In this task the number of added the first and second number should be inputted. The number shown was three digits in "low mental work load" condition, and four digit in "high mental work load" condition.

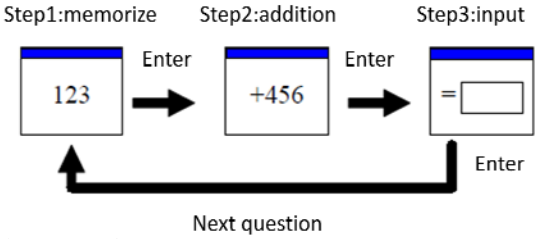

Fig. 4. Mental addition task

Experimental procedure. The experiment was conducted for one day per person. Figure 6 shows the experimental procedure in each day. After the time of explaining and practice of mental addition task, eight set of mental additional task were given to subjects. The time of one set is thirty minutes. After Each task, the questionnaire was conducted. And short breaks and long lunch time break was given among each tasks.

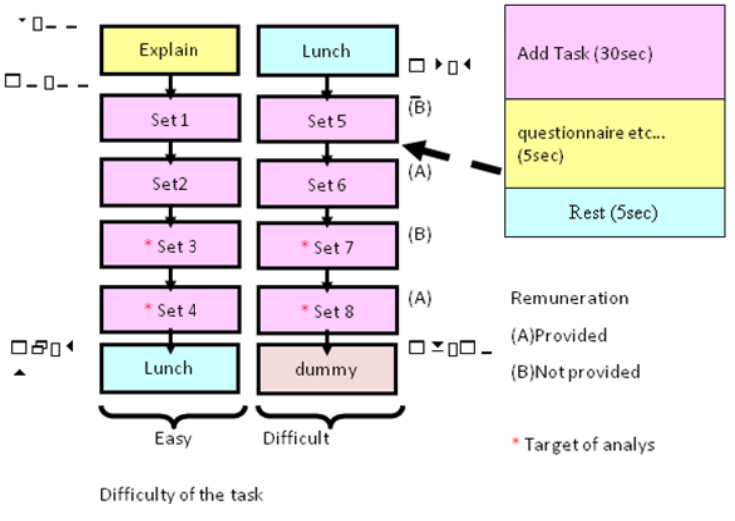

Fig. 5. Experimental procedure in a day

Measured Indexes. The performances of mental additional task were measured as performance indexes. Fatigue questionnaire examines the fatigue states of the subjects in five viewpoints which are sleepiness, discomfort, haze, instability and dullness. It consists of 25 questions and they are answered with five grades. Motivation questionnaire examines the subjective motivation from zero point to a hundred points. NASA-TLX examines the mental work load. From some question, mental work load is measured in one hundred degrees.

3.3 Experimental Results and Discussion

3.3.1 Task Performance and Inner Factors

Figure 6 shows the average of the performance indexes of each task set and the score of subjective motivation and NASA-TLX. As the result, providing additional payment improve their motivation, and the task performance in "high motivated" condition is higher than in "low motivated" condition ($p < 0.001$). And high difficulty of the task improve mental work load as shown in NASA-TLX score when the motivational condition was "high motivated" ($p<0.05$). On the other hand, there is no significant difference when the motivational condition was "low motivated". It may means that subject work easy at their own pace when low motivated, and it works mental work load to be fixed. However, these results don't have a particular meaning. This experiment was planned to get the result in which task performance is clearly changed.

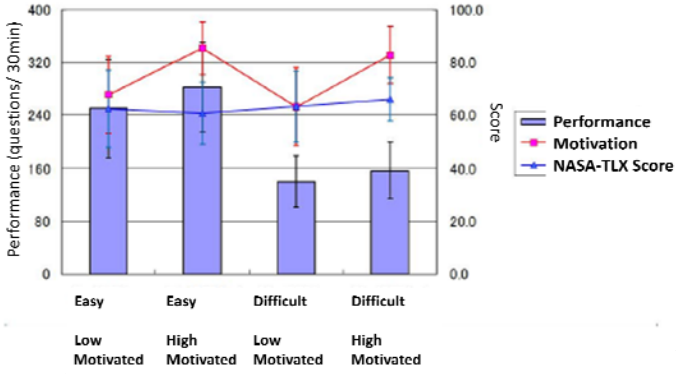

Fig. 6. Performance of mental addition task

3.3.2 Model Parameter

The model parameters in equation (1) to (3) to simulate experimental results have been examined with following method. When the four parameter a1, a2, v1 and v2 determined, a time line data of working is simulated by computer, for example, shown in top of figure 7. From this result, histogram can be made. By optimize the model parameters to minimize the similarity of the form of histogram of simulated result with one of experiment data. The similarity in examined as Error rate. It was defined, as shown in figure 8. By comparing the histogram of answering time, square sum of each variation between simulation result and experiment result was calculated. And, the parameter which makes the error rate smallest was calculated. Maximum likelihood estimation method was used to optimize. The parameters were determined for each task set of each subject.

Table 1 shows the average of the model parameters and result of significant test. And figure 9 shows the form of transition probability in high motivated and low motivated condition. When motivation becomes high, parameter a_1 became higher ($p<0.001$) and a_2 became lower. When mental work load becomes high (the task became difficult), parameter v1 and v2 become lower.

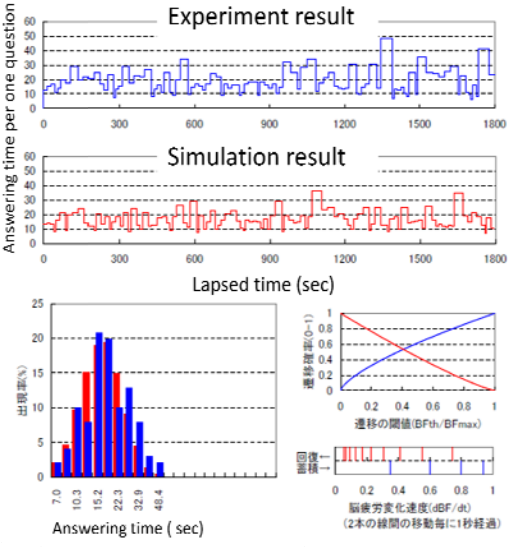

Fig. 7. Example of computer simulation result based on the model

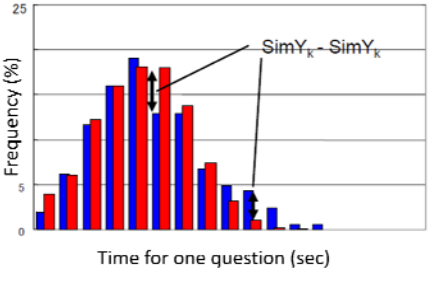

Fig. 8. Comparing the histogram of the simulation with experimental result

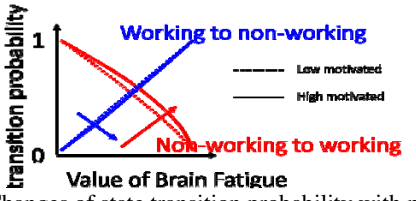

Fig. 9. Changes of state transition probability with motivation

Table 1. Model parameters and significance test for these parameters

	a_1			a_2			v_1			v_2		
Mental Work Load	Motivation			Motivation			Motivation			Motivation		
	Low	High	Variation	Low	High	Variation	Low	High	Variation	Low	High	Variation
Low MWL	0.93	1.03	0.10*	0.93	0.81	−0.13**	1.28	1.42	0.14	1.22	1.37	0.14
High MWL	0.99	1.07	0.08**	0.85	0.64	−0.21**	0.93	0.89	−0.03	0.92	0.89	−0.03
Both MWL	0.99	1.05	0.09***	0.89	0.73	−0.17**	1.11	1.16	0.06	1.07	1.13	0.06

	a_1			a_2			v_1			v_2		
Motivation	Mental Work Load			Mental Work Load			Mental Work Load			Mental Work Load		
	Low	High	Variation	Low	High	Variation	Low	High	Variation	Low	High	Variation
Low Motivation	1.03	0.85	−0.18*	0.89	0.94	0.05	1.03	0.94	−0.09	1.01	0.9	−0.11
High Motivation	1.08	1	−0.08	0.83	0.72	−0.12	1.25	0.79	−0.45***	1.2	0.78	−0.42***
Both Motivation	1.06	0.93	−0.13*	0.86	0.83	−0.04	1.14	0.87	−0.27***	1.11	0.84	−0.27***

*: p<0.05; **:p<0.01; ***:p<0.001

3.3.3 Discussion

By comparing the model parameter a_1 and a_2, it was found that the subjects tend to concentrate the task when their motivation is high. By comparing the model parameter v_1 and v_2, it looks the change speed of fatigue under high mental workload task is slower than low mental work load task. But high mental workload make the speed of accumulating fatigue slower looks opposite. Considering the change of working state simulated with the model, drop of the parameter v1 and v2 makes the time of a single working or non-working state longer. It means workers try to keep their attention to the task and take a long break instead when the task workload is high

4 Conclusion

In this study, the authors proposed a model which can explain and simulate the change of office work productivity. This model assumes office workers transit a working state and a non-working state with the probabilistic functions based on the variation of brain fatigue. Aiming to discuss the detail of the model, the authors have conducted a subject experiment in which work motivation are controlled. Comparing the results of the

experimental results with the result of computer simulation based on the model, it was found that the subjects tend to concentrate the task when the remuneration is provided, and they try to keep their attention to the task and take a long break instead when the task workload is high.

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