DEVELOPMENT OF A NEW COGNITIVE TASK TO MEASURE INTELLECTUAL CONCENTRATION AFFECTED BY ROOM ENVIRONMENT

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ABSTRACT

Recent studies show improvement of intellectual productivity brings great benefits, therefore the studies on office environment in order to improve an intellectual productivity have been actively conducted. However, there has been no established tool to measure the productivity quantitatively. Our laboratory has been developing a quantitative measurement method as a concentration time ratio (CTR) using the answering time data of receipt classification task as a task of uniformed difficulty. However, the answering time of the task includes time to turn over a paper receipt, which has little relation with cognitive activities, and the operation of the tasks has difficulties of preparing a huge number of paper receipts, and obtaining error rate of the answers.

In this study, therefore, a new cognitive task has been proposed in a useful and more suitable style for measuring the intellectual productivity. The new task is named “comparing task” and it includes two kinds of tasks which give abstraction of office work or learning activity. One is a word comparison task which requires an ability of language recognition and the other is a number comparison task which requires that of numeral recognition. The comparing task was realized on iPad application so that it can be conducted easily. In addition, it can calculate error rate which has not been obtained by the conventional task.

In order to assess the proposed task, two experiments were conducted. One experiment was to confirm that the task employs linguistic ability and numerical ability, cerebral blood flow was measured by NIRS when conducting the task. As the result, it shows activation of prefrontal area and Broca’s area. The other experiment was to confirm that the problems of the task has unformed difficulty enough to calculate CTR and to confirm that it has sensitivity to detect change of office environment. As the result, the calculated CTRs show the difference of environmental condition.

In the future, it is necessary to conduct more experiments using the comparing task and shows its usefulness.

Keywords: Indoor environment; Intellectual productivity; Thermal comfort; Task and ambient light

1. INTRODUCTION

As intellectual activity has been getting important in not only education but also our daily works, research studies on intellectual productivity have become popular these days. Many researchers and developers have been working on to promote the intelligent productivity by using various ways, in

order to gain lots of benefits (Land, Infrastracture and Transportation Ministry, 2009).

Recent studies have revealed that improvement of office environment may improve the intellectual productivity of office workers. In these studies, mainly four methods have been applied to evaluate the improvement of intellectual productivity caused by the improvement of office environment. They are (1)subjective evaluation(Sugiura, 2007), (2)physiological indices(Nishihara, 2007), (3)direct performance measurement of office work(Fisk, 2002) and (4)measurement of cognitive task performance(Throne, 1985). As a versatile and qualitative measurement method of intellectual productivity, (4)measurement of cognitive task performance has been often utilized .It is however difficult to accurately evaluate the change of intellectual productivity by the change of work environment because the performance is greatly influenced by learning effect. In order to solve this problem therefore CTR (Concentration Time Ratio) index has been proposed (Uchiyama, 2014).

Some cognitive tasks such as Stroop test (MacLeod, 1991) and GO/NO-GO test (Dubois, 2000), focus on the brain activity, and other cognitive tasks such as text-typing and simple-calculation task (Wargocki, 2000) focus on the concentration onto the task. However, the cognitive task dealt with in this study is given to measure intellectual productivities in office or studying environment, so that it should require the ability used in the office work and learning.

A receipt classification task has been employed as the cognitive task for CTR at present, which is a problem set of unified difficulty. The CTR index can be calculated from the distribution of answering time of the problems. However it has a physical limitation that thousands of paper receipts should be prepared in advance for the measurement. In addition, it also has other problems such that the measured answering time includes not only the cognitive activity but also a motion of turning over the receipts, that it is difficult to measure the error rate, that it may cause boredom because of low abstraction as a cognitive task or because of low difficulty after learning, and that the motivation for the task may change because they can see the progress of the task as remaining bunch of the paper receipts.

Although digitization of this task have been tried in order to solve the above problems, it could not duplicate the task because it often caused strong sleepiness so that the cognitive task using the paper receipts has kept to be employed until now.

The purpose of this study is, therefore, to develop a new cognitive task to measure intellectual productivity, which has less physical limitation and improves usability. In addition, it is able to measure error rate and the answering time is less influenced by the time except cognitive activity. It is expected that the intellectual productivity could be evaluated more accurately using the new cognitive task.

2. DEVELOPMENT OF A NEW COGNITIVE TASK FOR CTR

2.1 Calculation method of CTR and requirements for cognitive task

CTR is an evaluation method of intellectual productivity by calculating concentration time ratio during working time based on the hypothesis that their works progress while they are concentrating on them. The advantage of the CTR is that it can cancel learning effect which often appears when repeating cognitive task again and again.

Figure 1 shows the basic idea of CTR. Its idea originated from cognitive model by Cards(Card, 1983). In the concentration model, one of three cognitive states is assumed to appear alternatively while they are being employed intellectual work(Miyagi, 2012). The states are (1)working state, (2)short-term pause state and (3)long-term rest state. In (1)working state and (2)short-term pause state, their cognitive resources seem to be occupied to focus on the target work, while they seem to be taking

rest in (3)long-term rest state. In the concentration model, therefore, the states (1) and (2) are considered as concentration state while (3) is non-concentration state(Shimoda, 2013). When assuming the transition probabilities between (1)working state and (2)short-term pause state are constant and the primitive cycle time of the brain activity is also constant, the answering time of the problem shapes a log-normal distribution as shown in the right graph of Figure 1(Uchiyama, 2014). And the answering time at the right side of the graph which is not included in the log-normal distribution can be considered as the non-concentration state. By calculating the ratio of log-normal distribution among total working time, CTR index can be deduced.

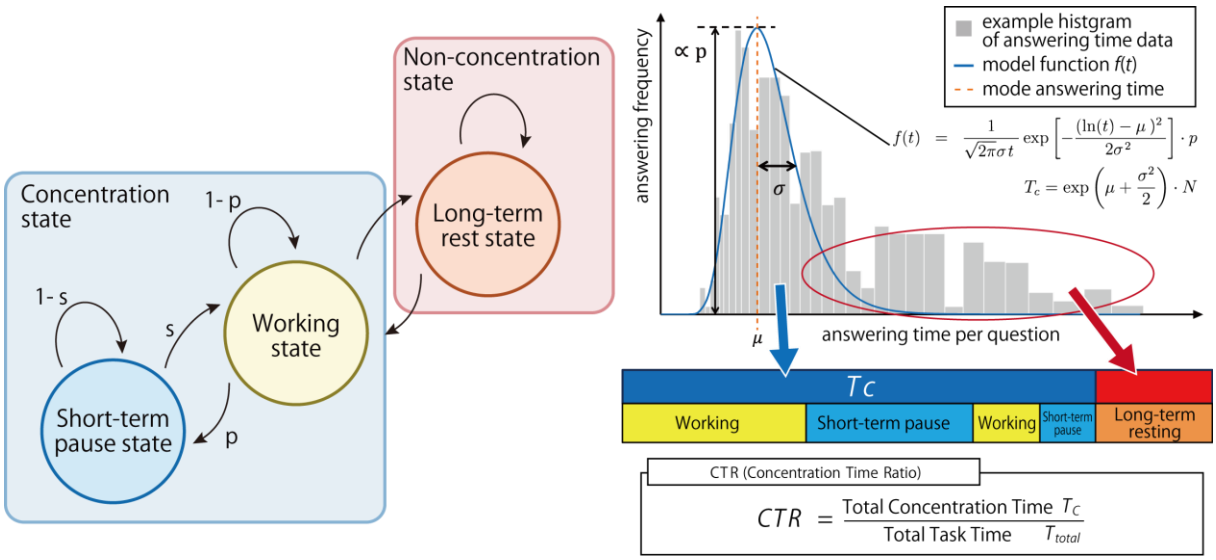

Figure 1. Concentration-Rest model and the method of calculating CTR

The cognitive task to be developed in this study should be a problem set to evaluate concentration affected by environments for office work and learning, and should be also suitable to deduce CTR. Therefore, the task should satisfy the following conditions;

- Linguistic and numerical abilities should be employed when solving the problems,
- All of the problems have unified and proper difficulties and
- Solving strategy has not change while conducting the task.

2.2 Comparison Task

The task developed in this study is called “comparison task” and it has been realized as an iPad application. Figure 2 shows an example screen. When solving the problem, they first look at the left half area and compare words and numbers, then touch one of the four buttons in the right half area to answer the problem. As shown in Figure 2, there are two factors to be compared, which are word comparison and number comparison. In the word comparison, they recall their meaning categories and judge whether the meaning categories of both words are the same or not. In the number comparison, they judge whether the inequality is correct or not. After these two comparisons, they are required to touch one of four buttons according to the results of the comparison. This task is simple and easy to be understood so that the learning time can be shortened. In addition, it needs both linguistic and numerical abilities which are necessary for intellectual work. The questions are simplified to avoid the changes of solving strategy and to shorten the learning time. The questions are designed to have unified difficulty, which can be realized hardly in actual office work or learning.

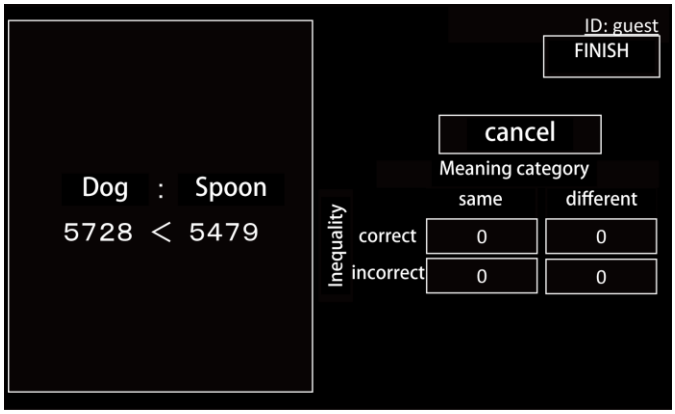

Figure 2. Example of the Comparing Task

Among the continuous solution of the problems, the priming effect may be seen both in the word comparison and the number comparison because the answer of the former problem may affect the latter. And another priming effect for the position of the answer button may also be seen. Therefore, to unify the difficulty, the order of the problems is decided by considering these effects.

In order to implement the comparison task, the software was described using html and JavaScript and it works on Web browsers. The example of the collected answering time data and their analysis result are shown in Figure 3.

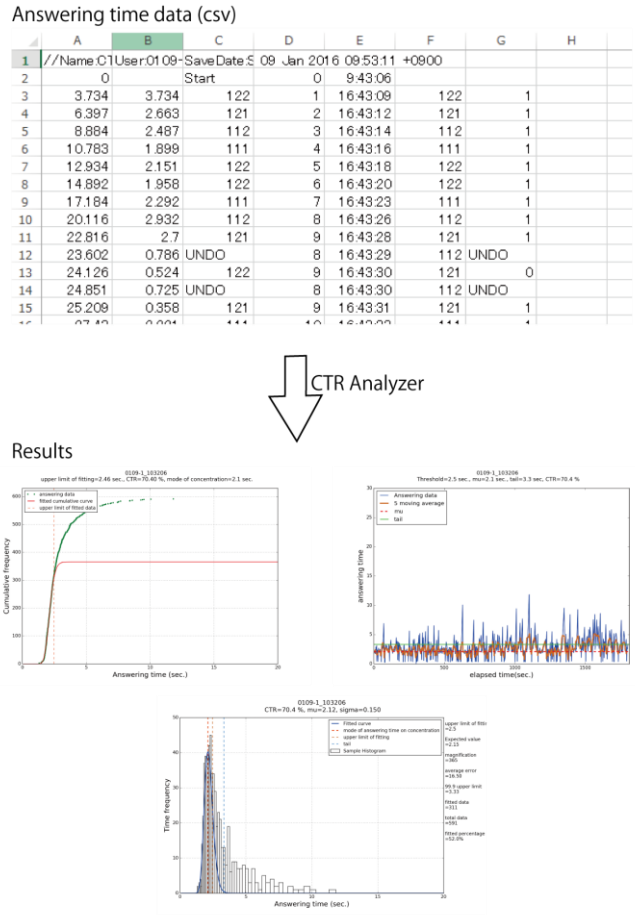

Figure 3. Example of the answering data and results of CTR analysis

3. EXPERIMENT

A subject experiment was conducted to confirm that the comparison task is feasible to deduce CTR index and can be utilized to evaluate intellectual concentration affected by room environment.

3.1 Experimental methods

The experiment was conducted for 5 days from January 9th to 13th in 2016 at an experiment room on the basement of a research building in Kyoto University. Totally 37 high school students and university students participated. The prepared room conditions are two for thermal environment (Cool, Hot) and two for illumination environment (Task and Ambient light; TA, Ambient light; A) so that totally four combinations were prepared as shown in Table 1.

Table 1. details of the environment of experimental room

Environment (thermal / light)	Task and Ambient (TA)	Ambient (A)
Cool (comfortable)	(Cool/TA) 21.0-22.0 degree Celsius 1800 Lux	(Cool/A) 21.0-22.0 degree Celsius 350 Lux
Hot (uncomfortable)	Hot/TA 25.0-26.0 degree Celsius 1800 Lux	Hot/A 25.0-26.0 degree Celsius 350 Lux

Figure 4 shows the experimental procedure. Besides the comparison task, SUDOKU puzzle task was given as a dummy task in order to avoid causing their boredom and to secure enough time to adapt the room environmental conditions. The concentration under TA condition was expected to be higher than that under A condition (Shimamura, 2014). Because of this expectation and experimental time limitation, the order of the illumination condition was fixed from A to TA, while that of the thermal condition was counterbalanced by participant groups.

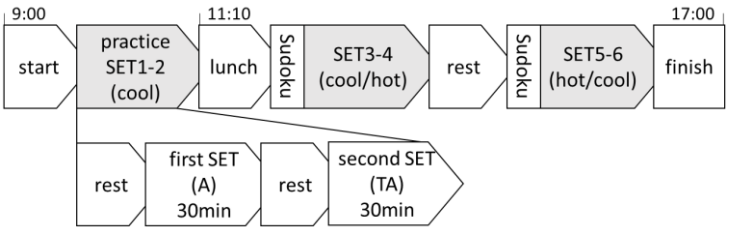

Figure 4. Protcol

In order to examine their impressions of the room conditions as designed, several questionnaire surveys about the environment were conducted just after the tasks. In addition, another questionnaire survey about their fatigue (Japan Society for Occupational Health and Working Group for Occupational Fatigue, 1988) was also conducted at the same time to check unexpected sudden change of their physical status.

3.2 Results and discussion

The results of all the participants could be acquired without deficit. Figure 5 shows an example of analysis result for answering time of the comparison task. The participant data when their physical

status or motivations were obviously changed during the tasks were omitted for the later analysis. The participant data which don't have enough number of answering time data for the approximation to the log-normal distribution were also omitted based on the standard of CTR analysis software. As the result of above omission, 26 participant data out of 37 remained as valid data.

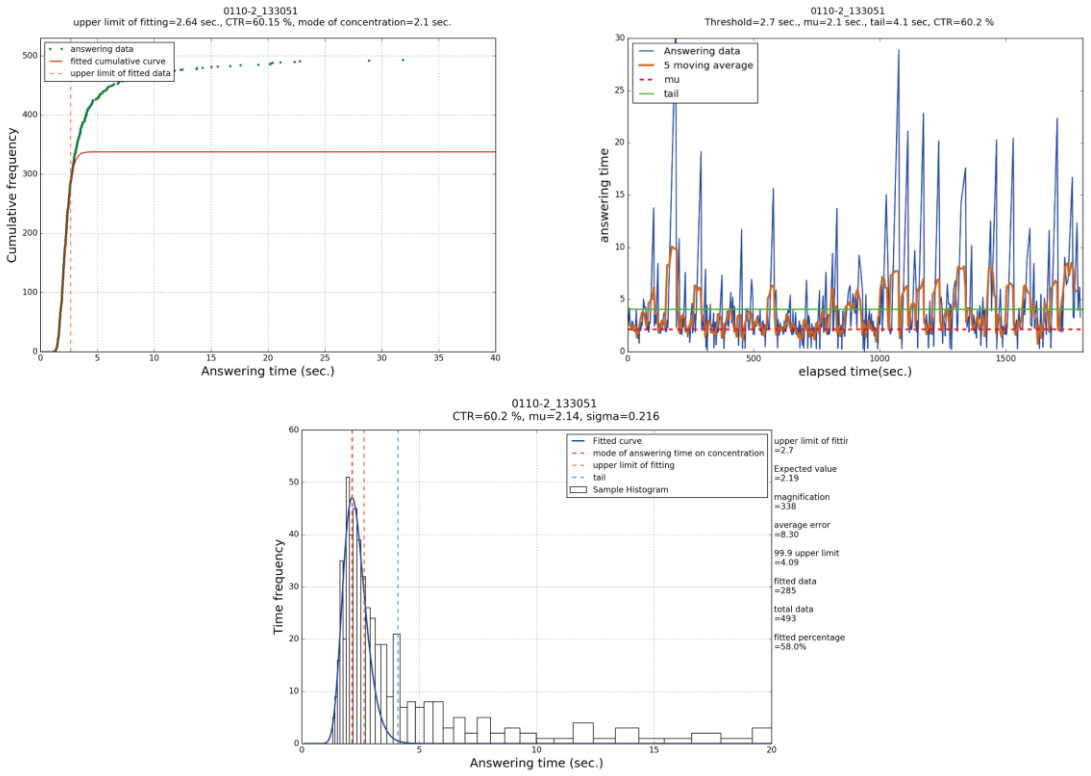

Figure 5. Example of results: the answering data and results of CTR analysis

Figure 6 shows the average and the standard deviation of CTRs and the error rates under four environmental conditions. Although the average CTRs under the Cool condition and A illumination condition seemed to be higher, no significant difference was found by ANOVA. There was no significant difference found in the error rates between the environmental conditions neither. On the contrary, the questionnaire results of some subjective evaluations for the environmental conditions gave significant differences and it was found that the participants had impressions as the designed experimental conditions. Figure 7 shows the questionnaire results of concentration under the conditions.

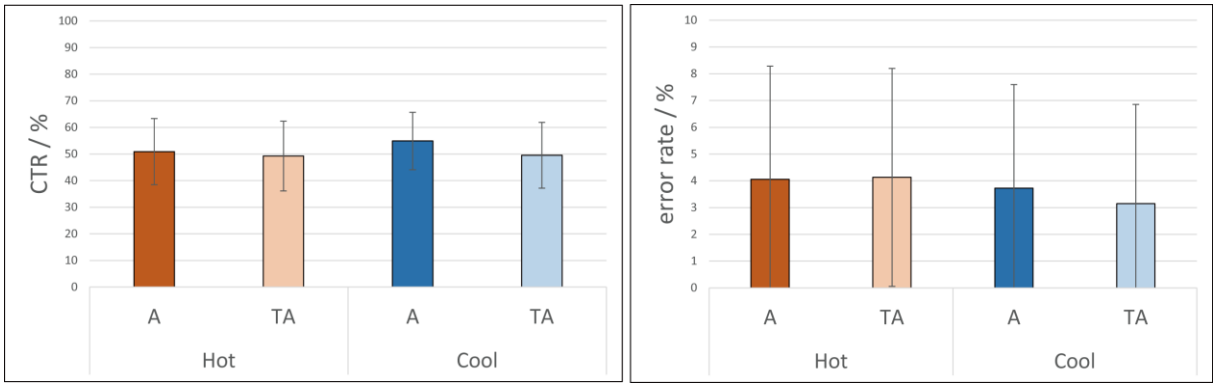

Figure 6. Results of CTR and Error rate

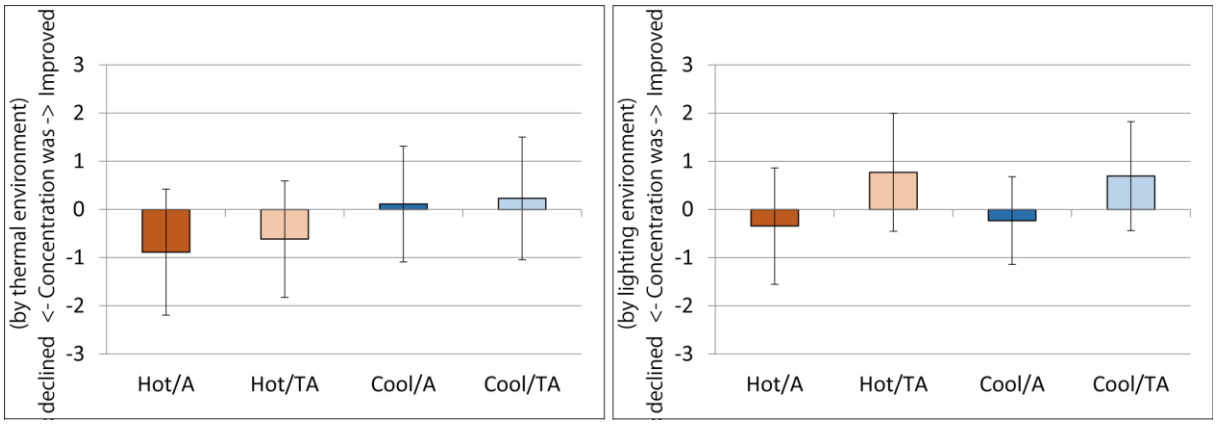

Figure 7. Results of subjective questionnaires about the indoor environment

The answering time data which were not feasible for the approximation to calculate CTR were only 3% of total acquired so that it was found that the comparison task could provide enough number of answering time data even in 30 minute task. In addition, it was also found that the difficulty of each problem is unified, that they had got learned to solve the problems quickly, and that their solving strategies had not changed while conducting the tasks. No significant difference was found in the error rate between the environmental conditions though, valuable data were obtained for further consideration to utilize the error rate such as combined use with the CTRs.

As the results of this experiment, the possibility has been suggested that the CTR index has sensitivity for concentration change caused by room environment even in the thermal condition which has been considered to give less influence. For the further study, it is necessary to design and modify the experimental procedures to control the accumulation of fatigue and improve the accuracy.

4. CONCLUDION

As the results of the experiment in this study, it was found that the developed comparison task was feasible for the CTR analysis to evaluate the concentration during intellectual work. By using the comparison task, the time necessary for environmental evaluation could be shortened because of the shorter learning time for the task. In addition, it could provide error rate of the problems and overcome the physical limitation of the conventional receipt classification task. The further practical used of the comparison task developed in this study can offer easy evaluation method of concentration evaluation for various environments.

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