Effect of Work Motivation on the Task Performance under the Different Thermal Conditions

Go Iwashita[1], and Shin-ichi Tanabe[2]

[1]Msashi Institute of Technology, Tokyo, Japan
[2]Waseda University, Tokyo, Japan

Corresponding email: iwashita@sc.musashi-tech.ac.jp

SUMMARY

The impact of the work motivation on the occupants' work performance of serial one-figure addition task and proofreading task was studied in two types of experiments, i.e., type A of cool condition (22 deg C) and type B of neutral condition (25 deg C). During the occupancy of 120 minutes under each condition, the subjects performed the above tasks with financially motivated situation and without motivated situation. The subjects also answered the questionnaire, which asked the indoor environmental quality and sick building syndrome symptoms during the conditions. It was found that there was significant difference in the performance of theses two tasks between the motivated situation and no-motivated situation. The shape of the performance curve for type A during no-motivated situation was similar to that during motivated situation. The performance of addition task was well correlated with the thermal acceptability vote during motivated situation. On the other hand, the good correlation was not found between the performance and thermal acceptability during no-motivated situation.

INTRODUCTION

Many researches in various research fields, such as occupational hygiene, ergonomics, psychology, architecture and so forth, have investigated the effects of indoor environmental factors on productivity since Vernon's research. He investigated the monthly output of five plating factories with monthly outside temperature and concluded that an output fallen along with the rise of temperature [1]. In the early stage of the psychological research on workplace, the effect of an environmental stimulus was considered to be uniform to everybody. Sundstrom *et al* mentioned that the relation between people and environment was mechanistic and deterministic [2]. They explain that, in theory, a person's response to the environment may involve several processes, which in turn will affect his/her performance. The main processes are, arousal, stress, distraction, overload, fatigue and adaptation. Sundstrom reports that mental tasks have generally been unaffected by heat whereas motor tasks have suffered in heat. As a result of the experiments the effect of various illuminance levels on the productivity of assembly workers was studied in Hawthorne Works, it was found that even decreasing the illuminance level increased worker productivity. It was thought that increased motivation could lead to increased productivity; this is commonly referred to as the Hawthorne effect [3].
In the work performance studies in Japan, the serial one-figure addition task has been used as an index of the productivity from prewar days. Since this task was developed as "Uchida-Kräpelin mental work test" in psychology, the performance curve of the one-figure addition task could be used to investigate a person's aspect of mental process [4]. Many researches on productivity studies in built environment use total amount of calculation of the addition task

within given time as an index of performance. However we use the performance curve as an index of his/her mental aspect [5].
The purpose of this study was to investigate the impact of the work motivation on the occupants' work performance of serial one-figure addition task and proofreading task in two conditions, i.e., type A under cool condition (22 deg C) and type B under neutral condition (25 deg C). During the occupancy of 120 minutes under each condition, the subjects performed the above tasks with financially motivated situation and without motivated situation. The difference between the performance conducted during motivated situation and that during no-motivated situation could be discussed.

METHODS

Experimental condition

The experiments were conducted in the test room shown in Figure 1. The room with two windows facing south had a floor area of 32m^2 and a volume of 96 m^3 (L×W×H=8×4×3). Two different thermal conditions were set up in the room as listed in Table 1: 1) type A, room temperature 22 deg C, 2) type B, 25 deg C. The air temperature was controlled by the air conditioner equipped in this room.

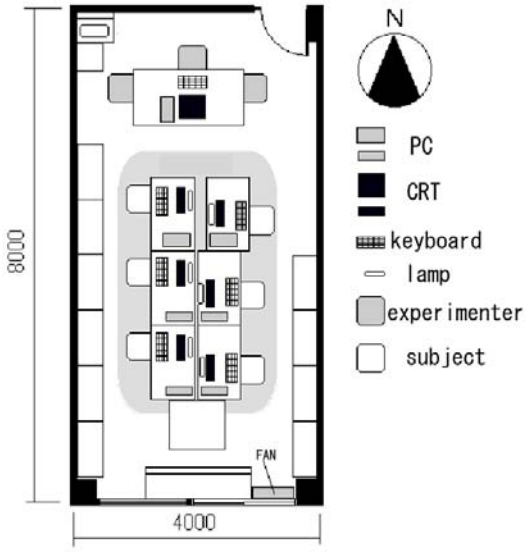

Figure 1 Experimental Room

Table 1 Experimental type

type	Room temperature	Relative humidity
A	22 deg C	40～
B	25 deg C	

Subjects sat at six workstations, each consisting of a table, a chair, a desk lamp and a personal computer (PC). Thirty female subjects participating in the present experiments were all students. The subjects were paid a salary for participating in the experiment at a fixed rate. To increase their motivation during the motivated situation, they were also paid a bonus of up to 15% of the total salary, depending on their performance.

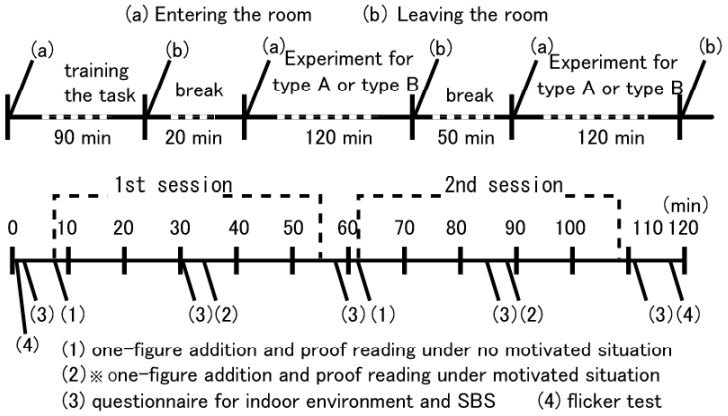

Figure 2(upper) Experimental procedure, (lower) Detail of the schedule for an experiment

Table 2 Questionnaire for indoor air condition

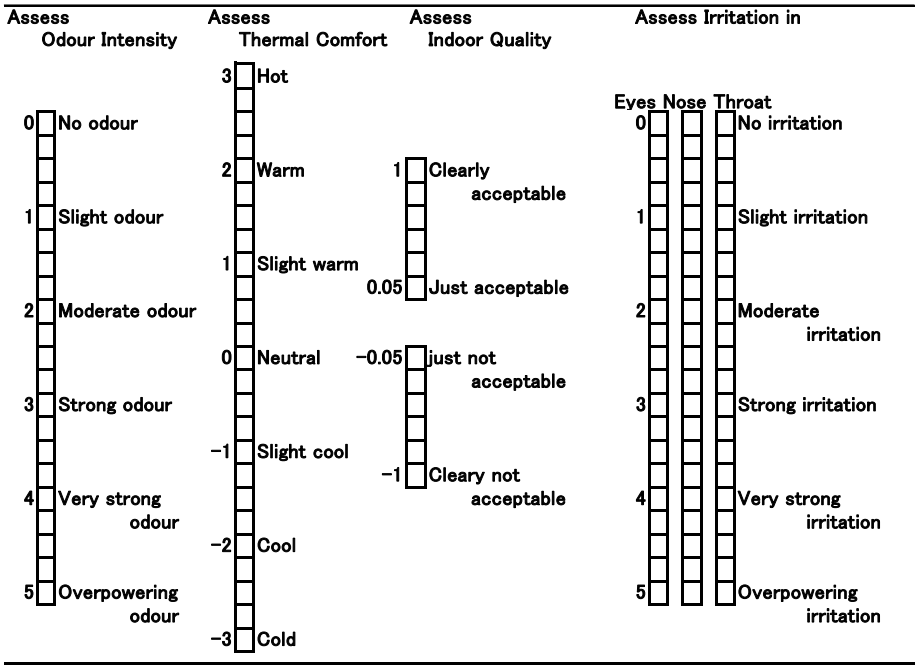

Table 3 Questionnaire for self-condition and SBS symptoms

Right now my environment can be described as follows:

	Extremely	Very	Slight	Neutral	Slight	Very	Extremely	
Too humid	☐	☐	☐	☐	☐	☐	☐	Too dry
Air stuffy	☐	☐	☐	☐	☐	☐	☐	Air fresh
Too dark	☐	☐	☐	☐	☐	☐	☐	Too bright
Too quiet	☐	☐	☐	☐	☐	☐	☐	Too noisy
	−3	−2	−1	0	1	2	3	

Right now I feel as follows:

	Extremely	Very	Slight	Neutral	Slight	Very	Extremely	
Nose blocked	☐	☐	☐	☐	☐	☐	☐	Nose clear
Nose dry	☐	☐	☐	☐	☐	☐	☐	Nose running
Throat dry	☐	☐	☐	☐	☐	☐	☐	Throat not dry
Mouth dry	☐	☐	☐	☐	☐	☐	☐	Mouth not dry
Lips dry	☐	☐	☐	☐	☐	☐	☐	Lips not dry
Eye dry	☐	☐	☐	☐	☐	☐	☐	Eyes not dry
Eye smarting	☐	☐	☐	☐	☐	☐	☐	Eyes not smarting
Eye feel itchy	☐	☐	☐	☐	☐	☐	☐	Eyes not itchy
Severe headache	☐	☐	☐	☐	☐	☐	☐	No headache
Feeling bad	☐	☐	☐	☐	☐	☐	☐	Feeling good
Tired	☐	☐	☐	☐	☐	☐	☐	Rested
Difficult to concentrate	☐	☐	☐	☐	☐	☐	☐	Easy to concentrate
Depresed	☐	☐	☐	☐	☐	☐	☐	Positive
Alert	☐	☐	☐	☐	☐	☐	☐	Sleepy
	−3	−2	−1	0	1	2	3	

Completion of tasks requires:

☐ 100% ☐ 90% ☐ 80% ☐ 70% ☐ 60% ☐ ( )% ☐ 0%

Experimental procedure

The experimental procedure is presented in Figure 2 (upper). The experiment was carried out for 7.5h from 9:00 to 16:30. Figure 2 (lower) shows in detail the schedule. From 9:30 to 11:00 subjects took the training for the tasks, i.e., serial one-figure addition and proof reading, used in the following experiments. After 30 minutes break, subjects participated the experiment of type A or type B (random order) for 120 minutes (11:30 – 13:30). Then subjects participated the experiments of type A or type B for 120minutes (14:20 – 16:20). For each experiment, subjects entered the room and approached their workstations. Once seated, they assessed perceived air quality, general perceptions of the environment, SBS symptoms and thermal comfort. These evaluations were made several more times during exposure in the experiment. The questionnaire for the indoor air condition is listed in Table 2 and for self-condition and SBS symptoms in Table 3. While exposed to the conditions in the room, subjects performed tasks. In 1st session, they performed serial one-figure addition task for 10 min. and proofreading task for 10 min. under no-motivated situation. After the no-motivated situation, they performed serial one-figure addition task for 10 min. and proofreading task for 10 min. under motivated situation. In 2nd session, the above tasks were repeated.

RESULTS

The measured levels of the general parameters describing the indoor climate inside the room are shown in Table 4. The average air-change rate of the room measured by tracer gas decay method was 0.8 h^{-1}.

Table 4 Measured room temperature and relative humidity

	Type A	Type B	Outdoor
Room temperature (deg C)	22.0±0.9	25.3±0.8	13.8±1.6
Relative humidity （%）	46±5	39±4	58±15

（average±SD）

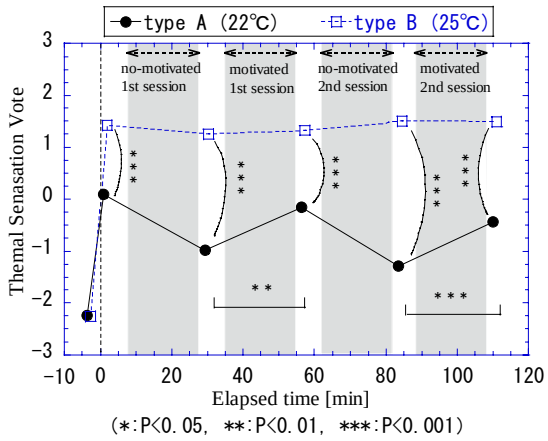

Figure 3 Thermal Sensation Vote as a function of time

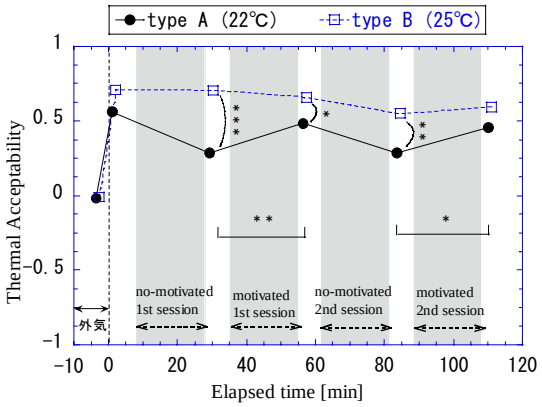

Figure 4 Thermal acceptability as a function of time

The average Thermal Sensation Vote (TSV) voted by subjects during no-motivated situation and motivated situation for type A was –0.7 and that for type B was 1.4. The average TSV value as a function time was presented in Figure 3. For type A, the average TSV values voted just after motivated situation was significantly higher (warmer) than those just after no-motivated situation. However there was no impact of the motivation on the TSV for type B.

Figure 4 shows the average thermal acceptability vote as a function of time. Since the experiments were conducted in autumn, subjects preferred the warmer condition of type B.
The average amount of calculation in one-figure addition task as a function of time is shown in Figure 5. There was no significant difference in the amount of calculation between type A and type B. On the other hand, the amount of calculation during motivated situation was significantly more than that during no-motivated situation both in type A and type B (P<0.01).

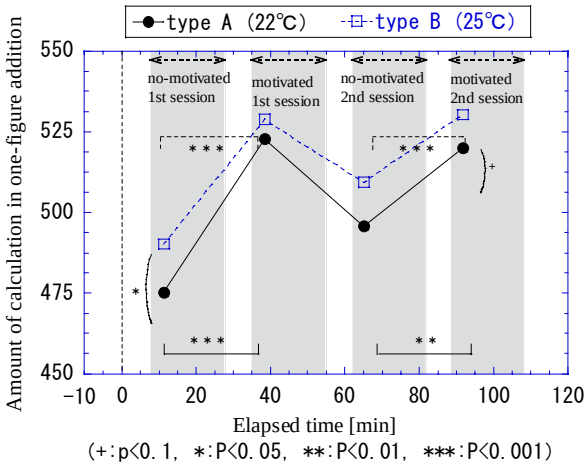

Figure 5 Average amount of calculation in one-figure addition task as a function of time

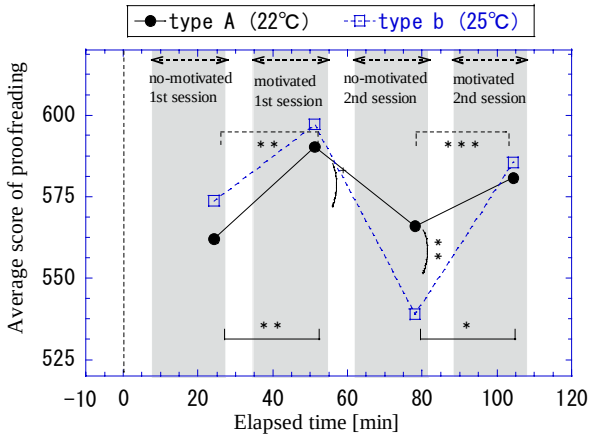

Figure 6 Average score of proofreading task as a function of time

The average score of proofreading task as a function of time is presented in Figure 6. Comparing the score of proofreading in type A with that in type B, the score in type A was significantly less than that in type B only during no-motivated situation in 2nd session. In terms of the motivation, it was found that the score during motivated situation was significantly more than that during no-motivated situation both in type A and type B as same as the result of one-figure addition task.

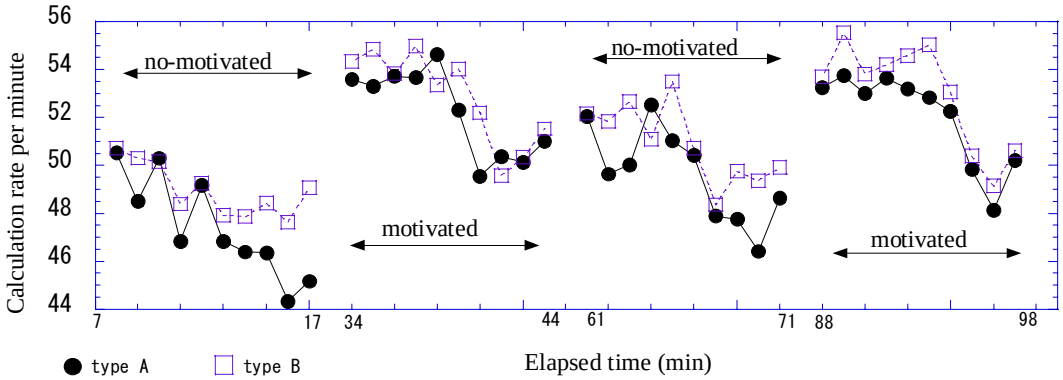

Figure 7 Average calculation rate per one minute as a function of time of one-figure addition task (ten minutes each)

In "Uchida-Kräpelin mental work test", the performance curve of the one-figure addition task has been used to investigate a person's aspect of mental process in psychology. Also for productivity study in the built environment, this performance curve was used to guess the mental process of subjects who were conducting tasks [5]. The average calculation rate per one minute as a function of time of one-figure addition task (ten minutes each) is shown in Fig.7. This figure shows that the calculation rate change curve (performance curve) had time decay trend. For each task, the calculation rate in the latter 4 minutes was much lower than

that in the first 6 minutes during no-motivated situation for type A. During motivated situation in 2nd session, the calculation rate in the first 6 minutes for type B was higher than that in the first 6 minutes for type A.
Therefore the calculation rates in the first 6 minutes and that in the latter 4 minutes for each experimental type were determined from the performance curve in Figure 7. The calculation rates during no-motivated situation were drawn in Figure 8 and those during motivated situation in Figure 9. The calculation rate in the latter 4 minutes for type B was significantly more than that for type A during no-motivated situation both in 1st session and 2nd session (Figure 8). On the other hand, the calculation rate in the first 6 minutes for type B was significantly more than that for type A during motivated situation in 2nd session (Figure 9).

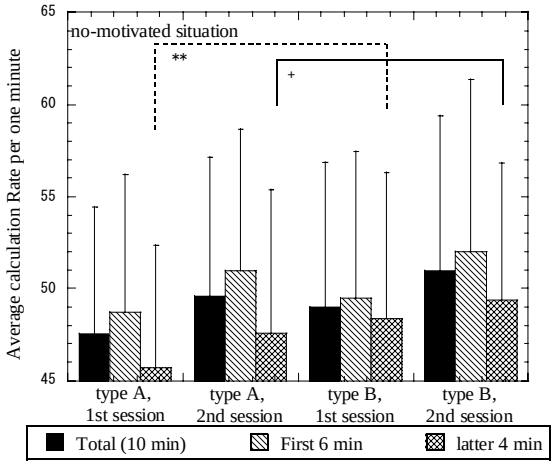

Figure 8 Average calculation rate for each session during no-motivated situation

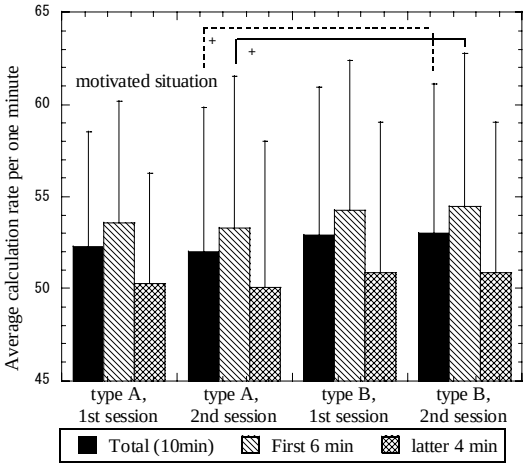

Figure 9 Average calculation rate for each session during motivated situation

DISCUSSION

While there was no large difference in performance curve between type A and type B during motivated situation, large difference was seen in calculation rate in the latter 4 minutes between type A and type B during no-motivated situation (Figure 7). The time decay trend was found in the performance curve for type A more remarkably than type B during no-motivated situation. The above time decay trend might be used for the index of arousal since this trend was seen during motivated situation. Figure 10 shows the relation between the average thermal acceptability and calculation rate in the first 6 minutes and that between the average thermal acceptability and calculation rate in the latter 4 minutes.
It was found that there was higher correlation between the calculation rate and the thermal acceptability during motivated situation than that during no-motivated situation. During motivated situation, arousal level of the subject could have been high because of the chance of bonus. Therefore lower arousal stimulus by indoor environment might have been needed during motivated situation. During no-motivated situation, arousal level of the subjects could have been low because of no chance of bonus. In this case, the subject performed more task in the cooler environment of the higher arousal stimulus even the thermal acceptability was low. In this study the thermal environment had no significant effect on the work performance during motivated situation. However there was effect of thermal environment by arousal on the work performance during no-motivated situation.

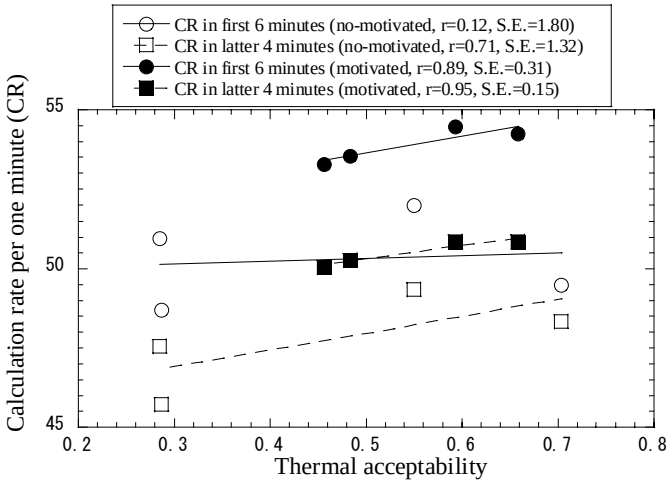

Figure 10 Relation between the average thermal acceptability and calculation rate in the first 6 minutes and that between the average thermal acceptability and calculation rate in the latter 4 minutes.

CONCLUSIONS

1) Thermal acceptability voted by subjects for type B (25 deg C) was significantly higher than that for type A (22 deg C) during no-motivated situation.
2) There was no significant difference in work performance (i.e., amount of calculation in one-figure addition task and average score of proofreading task) between type A and type B. For each experimental type, work performance during motivated situation was significantly better than that during no-motivated situation.
3) Performance curve, which presents the time change of calculation rate in one-figure addition task, showed time decay trend. During motivated situation, the calculation rate in the latter 4 minutes was much lower than that in the first 6 minutes. This time decay might be an index of the arousal. During no-motivated situation, the time decay trend was remarkable for type A.
4) It was found that there was higher correlation between calculation rate and the thermal acceptability during motivated situation than that during no-motivated situation. During motivated situation, arousal level of the subject could have been high because of the chance of bonus. Therefore lower arousal stimulus by indoor environment might have been needed during motivated situation. During no-motivated situation, arousal level of the subjects could have been low because of no chance of bonus. In this case, the subject performed more task in the cooler environment of the higher arousal stimulus even the thermal acceptability was low.
5) In this study the thermal environment had no significant effect on the work performance during motivated situation. However there was effect of thermal environment by arousal on that during no-motivated situation.

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