mental work-load, fasal skin temperature
physiological psychological evaluation,
intermittent type of MWL

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STUDY OF THE EFFECT OF INTERMITTENT TYPE OF MENTAL WORK-LOAD BY PHYSIOLOGICAL PSYCHOLOGICAL INDEX

This paper was aimed at evaluating the mental work-load (MWL) with psycho-physiological indices. Especially, we focused on the intermittent type of MWL, which is assumed as a predisposing factor of various somatic and mental disorders. In the experiment, we introduced a facial skin thermo image comparing with conventional physiological indices, such as electrocardiogram (ECG) and electroencephalogram (EEG). As a result, the facial skin image was suggested to be a useful tool for evaluating such an intermittent type of MWL.

1. INTRODUCTION

Recently, the highly information society comes with explosive development on the information technology. The work contents change greatly with this. Particularly, a ratio of the mental work rises very much in the work contents. It is said to give positive effects that the moderate mental work such as the improvement of the will. But, it is said to give negative effects that the too much mental work such as the fatigue, monotonous feeling, concentration fall for human. The load and the burden by the mental work are called a mental work-load [1]. It is said that MWL is distributed between two. One is a primary MWL evoked with a work start, and one more is secondary MWL evoked with continuation of work-load. The influence of primary MWL is only a transient mind burden. In the case of the influence of secondary MWL, mind burden and fatigue caused intermittent psychic strain, mind load, the distribution of the attention resource is added to this [2]. It is thought that secondary MWL become the factor of the healthy damage in the long term [2]. Therefore, it is very important to perform reasonable evaluation of MWL in the modern society for prevented human error and the healthy damage due to MWL. This study is tried to evaluate "Continuation of MWL". We used a mental arithmetic calculation task as a model of "the continuation of MWL" in this study. This task the high result of the plasticity is provided by a precedent study, but it is very restrictive. The effectiveness as the evaluation index of "continuation of MWL" are compared and inspected such as nasal skin temperature, brain waves (Electroencephalogram: EEG), a heartbeat (Electrocardiogram: ECG).

2. EXPERIMENT

2.1. EXPERIMENT ENVIRONMENT

We experimented that a characteristic and the effectiveness of evaluation of "Continuation of MWL" are inspected by nasal skin temperature. The experiment evaluates influence on mind and body for the mental arithmetic calculation task imposed repeatedly. Add it and other physiology psychology indexes to mention later with other physiological psychological indexes. Figure 1 shows mesurement system. This expriment was carried out in an electromagnetic shield room (The room width:3.8m depth:3.1m height:3.2m, Temperature: 25.0±1.0 degrees Celsius, Illumination: About 200lx, Windless). A subject is attached brain waves and a heartbeat conductive electrode. Thermography (TH3102 made in NEC SANEI) is put in a position of horizontal distance about 1m from the tip of nose of a subject. Thermal image size is 255×239 [pixels]. Thermal resolution is 0.08[°C]. Sampling frequency is 2[sec]. The derivation electrode of brain waves assumed four points (F3, F4, Fz, O2) based on international 10-20 methods. The electroencephalograph (EEG -2110 made in Nihon Koden) is connected through an electrode box (a pre-amp). In addition, the subject put on the electrode for the electrocardiogram measurement to three points (Instruction approximation Ⅱ). Three points are ” Left collarbone bottom fossa (N)”, ”right collarbone bottom fossa (-)” and ”becoming poor axilla borderline last place in the ranking rib (+)”. The electrocardiogram output is connected to the DC input department of the electroencephalograph through bead side monitor (BSM-3201 made in Nihon Koden). The sampling frequency of the electroencephalograph is 500Hz. The PC which is displayed a mental arithmetic calculation task is on the desk. A ten key to perform input is the place that it is easy to do of the work for a subject. A healthy adult subjects are ten. They are 21~31years old. This experiment was based on Helsinki Declaration (1964) by ethical consideration and carried it out.

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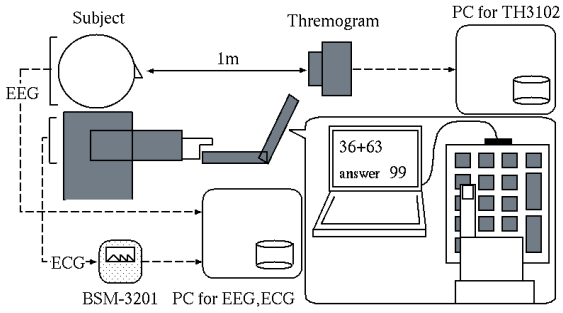

Fig. 1. Measurement system

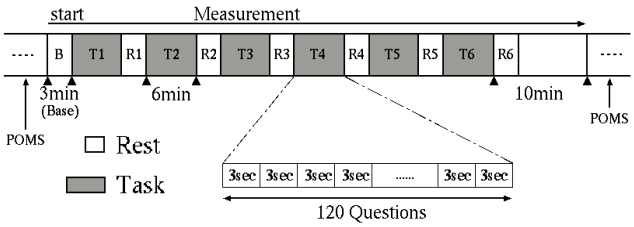

Fig. 2. An experiment schedule

2.2. MEASUREMENT PROCEDURE

Figure 2 shows schedule this experiment. A subject was performed of a mental arithmetic calculation task intermittently as "Continuation of MWL" on the personal computer. This task takes 6 minutes by one trial and one problem displays for 3 seconds. It is the question of addition of two columns without move up (one trial is 120 questions). The subject input the answer by ten keys during a number is displayed. The subject does 6 trials while taking a task of 3 minutes (36 minutes in total, 720 questions). The subject performs an operation exercise of the ten keys before beginning an experiment. To consider the custom of the subject to the measurement environment, the subject rests quietly for 15 minutes in sitting and eye opening state. The physiology index (a facial thermal image, brain waves and a heartbeat) begins a measurement for end three minutes in rest time. A measurement is finished when the subject takes the rest 10 minutes after the last task. "POMS" for a psychology index is measured in experiment before and after. All measurement time is 64minutes.

3. EVALUATION METHODS

3.1. ACTION EVALUATION AND A PSYCHOLOGICAL EVALUATION

In this study, we used the TSF (Time Shared Fraction) that is calculated by an expression (1) as action evaluation [3, 4]. TSF does not distinguish correct answer input from erroneous answer input for the issue of calculation. TSF is technique to evaluate a work load, based on time when the subject needed it for answer input for a problem presentation period. TSF expresses a ratio of the real information throughput for the greatest information throughput. It is said to be effective for an evaluation price of MWL [5].

$$TSF[\%] = (TA / TB) \times 100 \qquad (1)$$

where:

TA – A grand total of time before finishing pushing the key after a problem was shown
TB – Presentation time of problem)

For a psychology evaluation index, we use the POMS of Japanese edition. The POMS of Japanese edition is the test which is evaluated “condition of the feeling just now” by 65 questions. A POMS can be evaluated six factors that the subject physiological condition of the subject as tension and anxiety (T-A), dejection and depress (D), anger and hostility (A-H), vigor (V), fatigue (F) and confusion (C) [6].

3.2. A PHYSIOLOGICAL EVALUATION

A physiology index is measured by a facial skin thermal image, brain waves and a heartbeat change.

a) ***A facial skin thermal image*** We used the evaluation index which is difference of temperature of the forehead skin and the nasal skin (abbreviate it to NST). It is said that nasal skin temperature reflects activity of the autonomous nerve well. In addition, the sum region is located in the human trunk part, there are little bloodstream changes by the change of the autonomous nerve activity because density of Arteriovenous anastomoses (AVA) is low. Therefore, it can measure sthenia of sympathetic system and the parasympathetic system indirectly to measure a change of time of the difference of temperature with forehead skin and the nasal skin. Earlier study evaluated various measurement using a time change of NST [7-10].

b) ***Brain wave*** Performed frequency analysis to the brain waves, we get a Fmθ wave power (4~6Hz). It is said that Fmθ wave appears at the time of attention concentration. [11, 12] It is thought that it changes by the increase and decrease of MWL.

c) ***Heartbeat*** We used RRI and HF for an autonomous nerve index for MWL [11].

4. A RESULT

4.1. AN ACTION EVALUATION AND A PSYCHOLOGICAL EVALUATION

TSF for all mental arithmetic calculation tasks was about 75% in the action evaluation. Furthermore, as a result of one factor analysis of variance for TSF of six times of mental arithmetic calculation tasks, the effect of the repetition was not accepted ($F_{5,45} = 1.48$, $p > 0.05$). In addition, it was similar about a correct answer rate and the erroneous answer rate.

In POMS which is psychology evaluation, Vigor (V) decreased a significantly ($p < 0.05$). On the other hand, the significant difference was not recognized in the factor such as Fatigue (F), tension and anxiety (T-A) which changes big in a comparatively strong stressor.

Therefore, the mental arithmetic calculation task of this study can be said to have been monotonous simple "continuation of MWL" for a subject from both evaluation indexes.

4.2. A PHYSIOLOGICAL EVALUATION

Figure 3(a)-(d) show the change of the mean of each physiological data standardized every subject. (The each data was moving average processing in 20-30 seconds). The experiment result in NST, HF, Fmθ changes in the cycle along the calculation and rest schedule. In particular, NST reacted conspicuously at the experiment. In addition, HF is seems to increase during rest, adversely, Fmθ during a mental arithmetic calculation task. It is thought that it is a natural result couse that HF being the index of the parasympathetic and Fmθ being an index of the mind concentration.

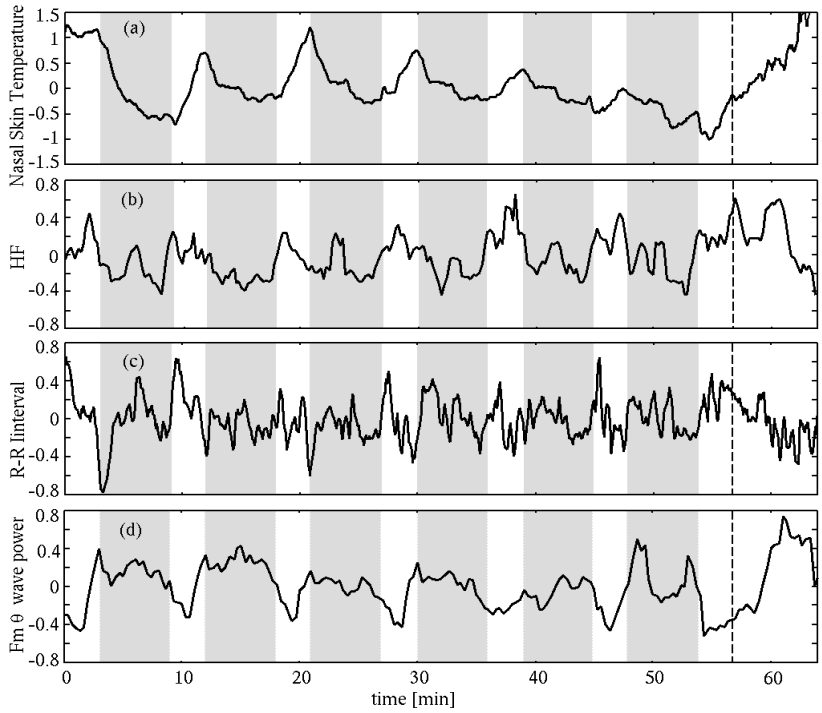

Fig. 3. Change of each physiological index.

Figure 4(a)-(d) show the mean and the standard deviation of each physiological index in experiment. It seems to be a difference in HF and Fmθ in the each section. Two factor analyses of variance (The T-R X repetition number of times) is performed about mental arithmetic calculation task and rest. A result, the main effect of the mental arithmetic calculation task was accepted for Fmθ and HF in four kinds of physiological indexes (Fmθ *:* $F_{1,54} = 4.74$, $p < 0.05$, HF *:* $F_{1,54} = 31.9$, $p < 0.001$). Therefore, it is said that HF and Fmθ is a good index when a mental arithmetic calculation is distinguished from a task. But the effect which is purpose of this study by the repetition number of times of "continuation of MWL" was recognized in neither index (All $p > 0.05$).

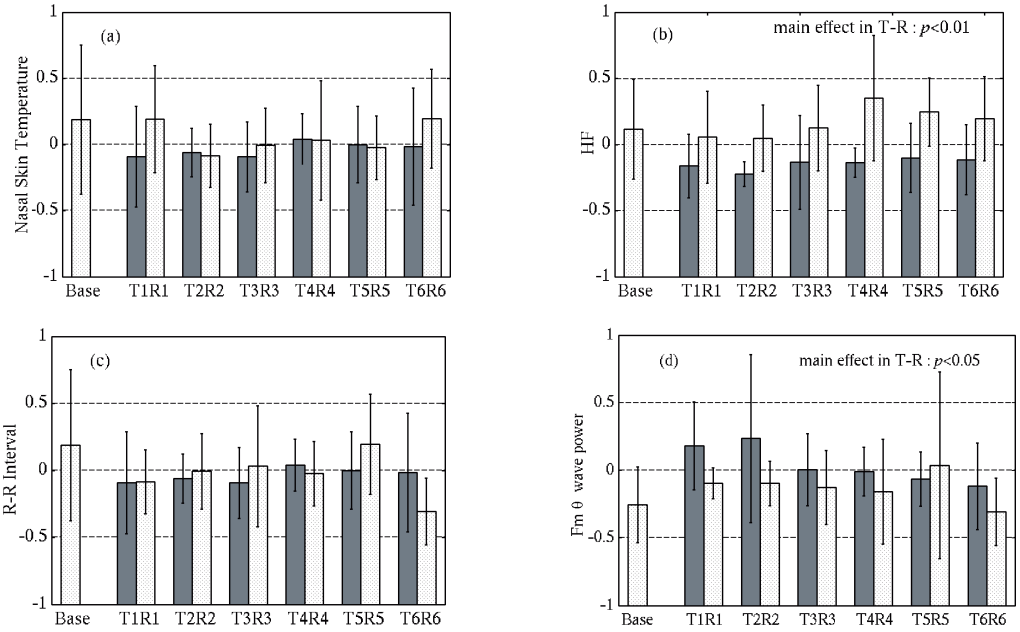

Fig. 4. Quantity of change of each physiological index.The average and SD in the section that six times of mental arithmetic calculation task(T1-T6) and rest(R1-R6). (”Base” is a value before the experiment start)

Figure 5(a) shows a result of NST. Distinction of a calculation and the rest is clear in NST. (For comparison, figure 5(b) shows the change for the HF). As a result of analysis of variance, the main effect of the mental arithmetic calculation task was accepted only in NST among four kinds of physiological indexes ($F_{1,54} = 112$, $p < 0.001$). But the effect of the number of times was not accepted in the change speed statistically repeatedly either (All $p > 0.05$).

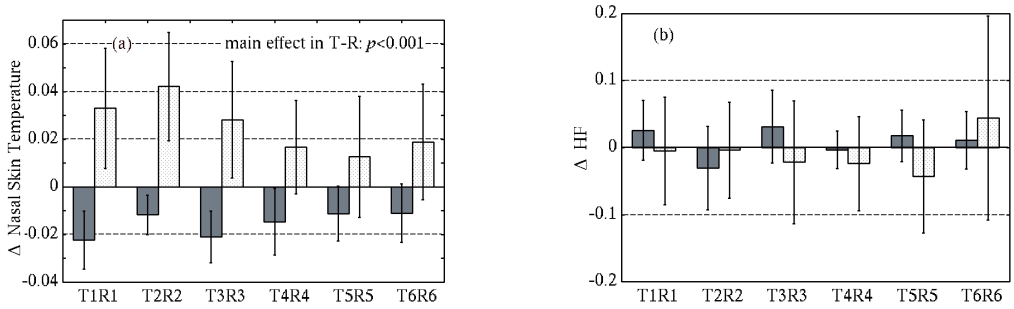

Fig. 5. The average and SD of the quantity of change in the section in six times
of mental arithmetic calculation task (R1-R6) of each physiological index.: (a)NST,(b)HF

We paid attention to the value of each mental arithmetic calculation task start point in time of T1-T6 and analyzed it. The value (R6e) added just after the last rest to analysis. As a result, a difference by the number of times was recognized only in NST (figure 6), furthermore, it was able to confirm a tendency to decrease after T3. When one factor analysis of variance (the repetition number of times) performed for the data, the main effect of the number of times was accepted only in NST ($F_{6,54} = 4.90$, $p < 0.001$). In addition, significant difference was recognized in experiment start time and the second end case, T6 and R6e in the multiple comparison.

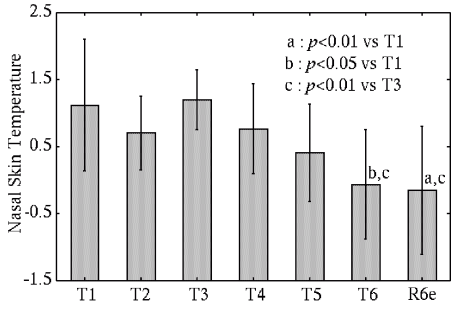

Fig. 6. A mental arithmetic calculation task startpoint in time
(on and, R6 end point in time) The average and SD of NST in R6e.

5. CONCLUSION

In this study, we pay attention to "continuation of MWL". We compared and inspected with a characteristic and the effectiveness as the nasal skin temperature and the other evaluation index in various physiological evaluation index. As a result, for a nervous system index to show reflective reaction for a mental arithmetic calculation task and rest, nasal skin temperature had the reaction characteristic slowly. It was shown that this slow reaction characteristic enabled "continuation evaluation of MWL".

BIBLIOGRAPHY

[1] NACHREINER F., International Standards on Mental Work-load –The ISO 10075 Series-, Industrial Health,37(1),pp.125-133,1999.
[2] S.HAGA, Theory and measurement of MWL, Japanese publication service, 2001.
[3] K.HIOKI, A.NOZAWA, T.MIZUNO, and H.IDE, Physiological Evaluation of Mental Workload in Time Pressure, T.IEEJ Trans.EIS, 127(7), pp.1000-1006, 2007.
[4] K.TAKANO, K.YOSHINO, A.NAGASAKA, BASIC RESEARCH ON MEASUREMENT OF MENTAL WORK LOAD UTILIZING PHYSIOLOGICAL INFORMATION, Japanese journal of industrial health, 32(2), pp.105-117, 1990.
[5] F.YAMADA, Minimum psychology for medical behavioral sciences, Kitaouji shobo, 1997.
[6] D.M.MACNAIR, M.LORR, Profile of Mood States, Success bell, Kanekoshobo, 1994.
[7] A.NOZAWA,H.MIZAWA,T.MIZUNO,H.TANAKA and H.IDE, Evaluation of the Driver's Mental Workload by Conversational Form based on Facial Skin Thermal Image Analysis, IEEJ Trans.SM, 126(8), pp.412-418, 2006.
[8] R.SAKAMOTO, A.NOZAWA, H.TANAKA, T.MIZUNO, and H.IDE, Evaluation of the Driver's Temporary Arousal Level by Facial Skin Thermogram –Effect of Surrounding Temperature and Wind on the Thermogram-, IEEJ Trans.EIS, 126(7), 804-809, 2006.
[9] H.IWATA, Quantitative Evaluation of Mental Work by Thermography, Transactions of the Society of Instrument and Control Engineers, 24(2), 107-111, 1988.
[10] S.NOMURA, H.TANAKA, T.MIZUNO, A.NOZAWA, T.NAGASHIMA and H.IDE, Evaluation of the Effect of Web Surfing on Human -Introducing Human Secretary Immune and Endocrine Indices, The IEICE transactions on information and systems, J-91D(4), pp.1158-1167, 2008.
[11] Advanced Industrial Science and Technology - Institute for Human Science and Biomedical Engineering, Handbook of Human measurement, Asakura publisher, 2003.
[12] H.MIYATA, New physiological psychology (Vol.2) An applicable field of the physiological psychology, Kitaouji publisher, 1997.