# Emotion Spectrum Analysis for Daily Repetitive Mental Workload

Akio Nozawa and Keita Karita

*Graduate School of Meisei University*
*(Tel: 81-42-591-5895; Fax: 81-42-591-5895)*
*(lily@biel.ee.meisei-u.ac.jp)*

***Abstract***: In this study, a mental workload for daily mental arithmetic training was objectively evaluated by physiological indices using the emotion spectrum analysis for the group with daily mental arithmetic training. Physiological measurement on mental arithmetic task was conducted once a week for subject. Physiological indices measured were alpha-wave power spectrum, beta-wave power spectrum, Fm$\theta$-wave power spectrum, variation in nasal skin temperature and high frequency component of heart rate variability. And depressive tendency for the mental arithmetic task was measured as psychophysical index by using POMS (Brief Form), and time duration for the mental arithmetic task was also measured as performance index. Correlation between physiological indices, psychological index, performance index, and emotion spectrum analysis was analyzed in relation of mental workload.

***Keywords***: Mental workload, Emotional spectrum analysis, Physiological measurement, Mental arithmetic task

## I. INTRODUCTION

In ubiquitous society in the future, the opportunity to use the telecommunication equipment by various scenes in daily life will increase. However, a benefit of ubiquitous society as "obtaining information anywhere anytime" may cause the risk in "using information and communication machinery for anywhere anytime." For example, with informatization in an automobile, causation with operation of information technology devices in the automobile and the accident has been pointed out. On the other hand, the driver's physiology psychology has been measurement from a safe viewpoint for the prevention of the car accident [1-5]. Mental activity is called mental work (MW), and a load given by MW is called Mental Workload (MWL). The continuance of excessive MW increases MWL, which will become the factor of a human error and health problems. For example, where high accuracy and safety are demanded, the worker is forced to have the strain for a long time. MWL increases while working like this and the incidence of a human error increases. The method of measuring MWL has been researched from the viewpoint of a human factor in the field where risk management like the aerospace field etc. is demanded [6-7].

In general, MWL is evaluated by the performance indices, the subjective psychology indices, and the physiology indices. Objective and quantitative evaluation in the real time are possible, and the evaluation method based on physiology indices has the advantage in detection of the reaction under the unconsciousness.

MWL does not merely depend on the objective degree of difficulty of the MW task. It is analogized by the experienced fact that MWL is related to a task performance, motivation, habituation, proficiency and so on. However, the personal attribute of MWL which evaluated quantitative with physiology indices are not investigated. From the viewpoint of stress management, serial assessment for the effect in physiology indices for daily MWL is the issue, which is the essential for the development of the technique of quantizing the MWL by physiological indices. Objective assessment of physiology indices have been studied about the influence of repetition of MW task proficiency by Fm$\theta$-wave [8]. On the other hand, the examination about the change of emotion about the repetition of the MW task has not been studied. Emotional Spectrum Analysis (ESA) is emotion estimation method by the physiology indices, which is Electroencephalograms (EEG). The ESA calculates four independent emotion vectors from coefficients of correlation between EEG signals measured by scalp electrode, which express the state of the brain and the state of mind [9]. In this study, EEG was focused as the physiology index, and MWL evaluated by psychophysiological index which was ESA derived from EEG measurement was serially assessed. The MW task was mental arithmetic task, which is Hundred Cell Calculation Method (MAT). The subjects trained MAT everyday routinely and psychophysiology measurement experiment for MAT performance was

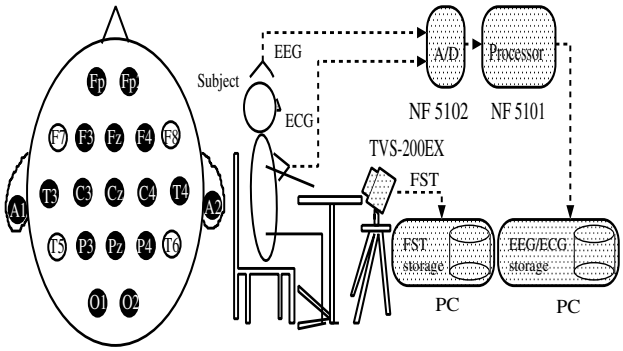


**Fig.1. Measurement system and EEG electrode arrangement.**

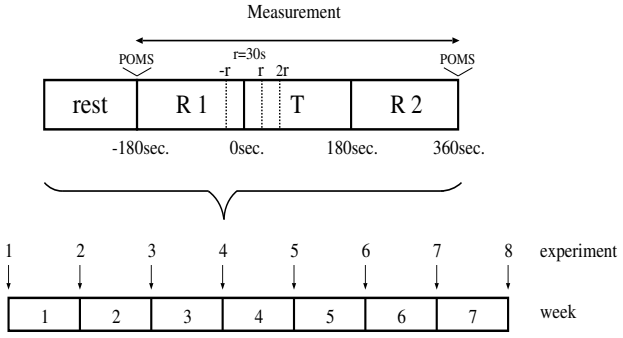


**Fig. 2. Experiment protocol**

conducted once daily. The physiology index is $\alpha$-wave $\beta$-wave and $\theta$-wave of electroencephalogram (EEG), nasal skin temperature (NST), and high frequency ingredient (HF) of the electrocardiogram (ECG). In addition, Japanese edition of POMS in short form (POMS) was measured as the psychology index. The performance index was task-elapsed time of MAT.

## II. EXPERIMENTAL

Experimental equipment setup and electrode arrangement for scalp EEG are shown in figure 1. Experiments were executed in a measurement booth divided with partition walls of 1.8m in height. An infrared thermograph system (TVS-200EX, AVIONICS) was installed 0.7m in front of subject. Facial skin thermograms were created with 1s sampling periods. Image resolution of thermograms was 320×240 pixels, and room temperature was set at 26±1.0 degrees Celsius. a seated position in a resting. An electrode headpiece (Pasteless Electrode Helmet, Brain Function Laboratory) and set of headphones were placed on the subject. EEG was recorded at a sampling frequency of 200 Hz using a biological amplifier/sampler (5102 EEG HEAD BOX, NF Electronic Instruments) and digital

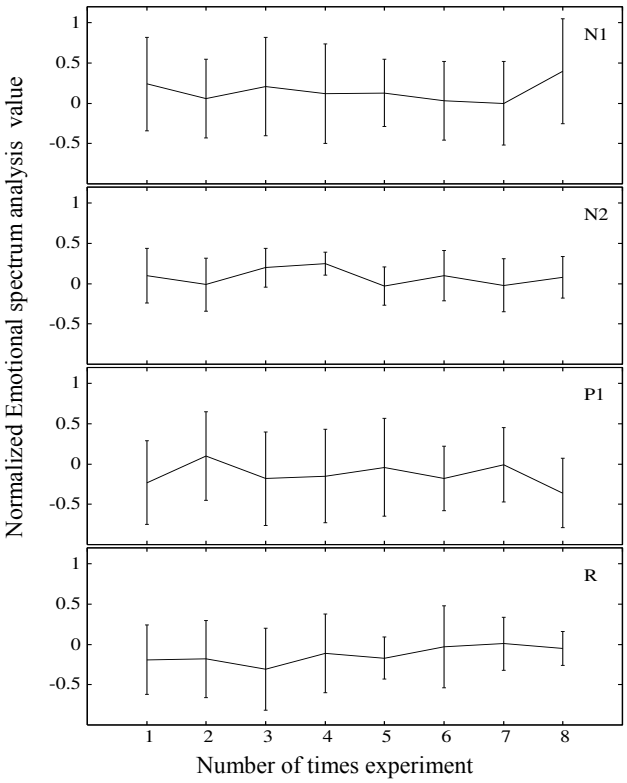


**Fig. 3. Variations of emotional spectrum in experiments.**

signal processor unit (5101 PROCESSOR BOX, NF Electronic Instruments). Electrodes used for scalp for scalp EEG were Fp1, Fp2, F3, F4, P3, P4, O1, O2, T3, T4, C3, C4, Fz and Pz, based on the international 10-20 method, and a reference electrode was A1 and A2. Electrodes used for ECG were put on the superior margin of the sternum and cardiac apex based on a modified Lead NASA in order to reduce artifacts of EEG from ECG. A common ground electrode for both EEG and ECG was put on Cz.

The protocol for the experiment is shown in figure 2. Subjects were eight 20- to 23-year-old healthy men. Subjects were well informed about the experiments and the objective of this study before participation experiments. In this study, The MAT was Hundred Cell Calculation Method of the multiplication. The experiment was performed for seven weeks and subjects trained MAT once a day at home. Psychophysiology measurement of the MAT performance was conducted once a week. The day of experiment could be before or after the day scheduled. The measurement was not begun until the subject had been in the room for at least 15 minutes to habituate to the room temperature. The measurement consisted of 3 periods time series, which

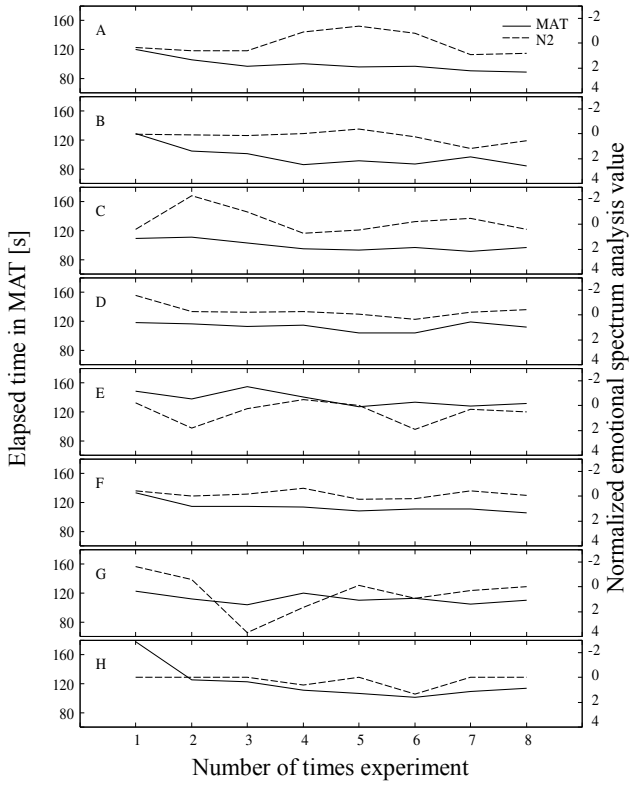


**Fig. 4. Relationship between MAT and N2.**

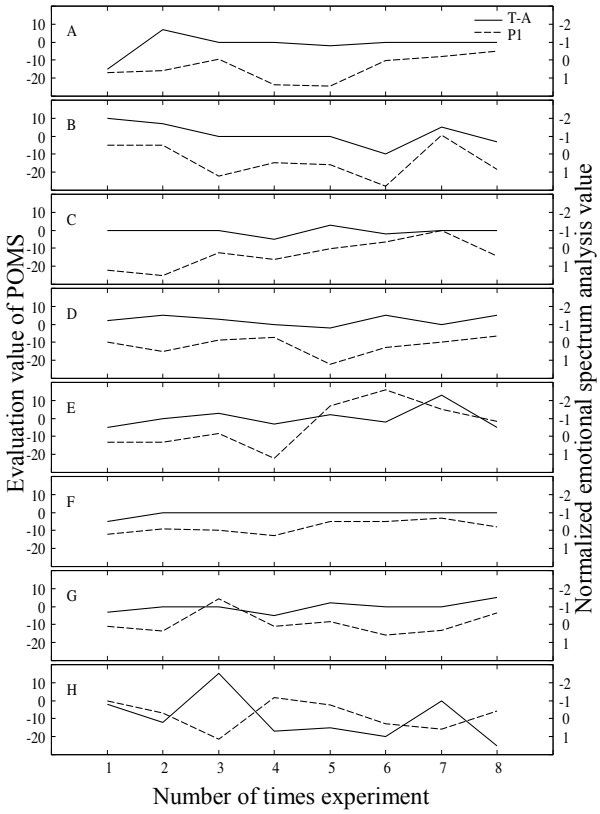


**Fig. 5. Relationship between T-A and P1.**

were 3-min eye-closed resting period (period R1), 3-min eye-opened period under controlled stimulation of the MW task (period T), and 3-min eye-closed resting period (period R2). Japanese edition of POMS(in short form) was measured before and after the measurement as a psychology index of the trend of dejection for the MAT task. POMS had 30 questions used to evaluate a trend of dejection and could measure the state of temporary feelings. The experiment was conducted during the day except within 2 hours after eating.

## III. RESULTS AND DISCUSSION

In this study, correlation of time of performance index, psychology index and physiology index was analyzed. The $\theta$-wave, $\alpha$-wave and $\beta$-wave power spectrum of EEG, the high frequency component of heart rate variability (HF) of ECG and NST time series were extracted from analyze of measured physiological data. The $\theta$-wave, $\alpha$-wave and $\beta$-wave show total brain activity. HF represents parasympathetic nervous system activity. Decreasing NST time series indicates sympathetic nervous system's activation. HF time series was calculated as follows. A source R-wave interval time series was extracted from ECG time series by using threshold processing. Temporally equidistant R-wave intervals (HRV) were derived by resampling process in frequency of 20 Hz after cubic spline interpolation. The power spectrum time series of HRV was calculated every 1s by fast Fourier transformation (FFT) using 512 data points at a sampling frequency of 20 Hz. Finally, HF time series was created as a summation of discrete frequency components in power spectrum time series of HRV, in which the frequency range of HF was 0.15 Hz to 0.4 Hz.

$\theta$-wave, $\alpha$-wave and $\beta$-wave time series were calculated as follows. The power spectrum time series of averaged EEG lead from O1 and O2. And it calculated every 5s by FFT using 1024 data points at a sampling frequency of 200 Hz. $\theta$-wave was defined as frequency components of the EEG in frequency range of 5 Hz to 8 Hz, 8 Hz to 13 Hz defined of $\alpha$-wave, and that of 13 Hz to 20 Hz defined of $\beta$-wave. The q-wave, a-wave and b-wave power spectrum time series were created as a summation of frequency components in each frequency range.

NST time series was calculated as follows. Thermal images of nasal region were extracted from facial skin thermograms (FST) time series by using template matching method, which the template was a partial image sampled from the first FST image. Then, NST time series was created as a cascade of spatial average temperature for pixels in each thermal image of nasal region.

Figure 3 shows variation of average emotion vectors between period R1 and period R2 of subjects.

Emotion vector was normalized against the temporal average of entire interval. The error bars here represent standard deviation. In the figure, N2 (stress), N1 (sad), P1 (pleasant) and R (relax) represent emotion vector respectively. There is no statistical significant difference (by Friedman test). A correlation analysis of emotion vectors and other indices was performed. Figure 4 shows relationship between the elapsed time of MAT performance and emotion vector N2 (stress). Negative correlation is provided in seven subjects. This figure shows that N2 (stress) increases while the elapsed time of MAT is shortened. It is considered that subjects had acquired proficiency in MAT and might get bored and annoyed with MAT. Figure 5 shows the relationship between POMS (T-A) and emotion vector P1 (sad). Negative correlation was provided in eight subjects, where correlation coefficients were from -0.32 to -0.88. The figure indicates that emotion vector P1 (sad) rises while POMS (T-A) declines. Estimated 'sad' feeling by the emotion vector agrees with a psychology index and shows that emotion vector is effective in estimation for repetitive MWL.

## VI. CONCLUSION

In this study, perform an MW task repetitive to evaluate the effectiveness of the ESA of repetitive MWL and evaluated it with physiology index psychology index and performance index temporal. As a result, in repetitive MWL, the effectiveness of the ESA was shown.

## REFERENCES

[1]Y. Nishio and M. Suzuki: "Evaluation of Human Arousal Levels through Physiological Responses," OMRON TECHNICS, Vol. 38, No. 2, pp. 184–190 (1998)
[2]S. Kumakura, T. Hara and Y. Goi: "Predicting Changes in Drivers' Drowsiness Level During Prolonged Driving: Etractinglong blinks from EOG data," Transaction of Society of Automotive Engineers of Japan, Vol. 29, No. 1, pp.155–159 (1998)
[3]T. Asao, J. Ishimura, T. Wada and K. Tsukamoto: "Influence of Conversational Contents on Driving Behaviors," Transaction of Society of Automotive Engineers of Japan, Vol. 35, No. 2, pp. 205–210 (2004)
[4]W. Wierwille and L. Tijerina: "An analysis of driving accednt narratives as a means of determining problems," Z Verkehrssicherheit, Vol. 41, No. 4, pp. 164–168 (1995)
[5]T. Ishida and T. Matsuura: "Mobile Communication in Transport, The Effect of Cellular Phone Use on Driving Performance,"IATSS Res (Int Assoc Traffic Saf Sci),Vol. 25, No.2, pp.6–14(2001)
[6]G. Reid and T. T. Nygren: "The Subjective Work-load Assessment Technique: A scaling procedure for measuring mental workload," Human Mental Workload, pp. 185–218 (1988)
[7]S. G. Hart and L. E. Staveland: "Development of NASATLX (Task Load Index): Results of empirical and theoretical research,"Human Mental Workload, pp. 139–183 (1988)
[8]S. J. Laukka, et al: "Frontal midline theta related to learning in a simulated driving task," Biological Psychology, Vol. pp. 313-320 (1995)
[9] T. Musha: "Estimation of Emotional State by EEG and its Limitation", Journal of the Japan Society of Mechanical Engineers, Vol. 105, No. 1006, pp.610-611 (2002)