

SKIN TEMPERATURE AS A POSSIBLE INDICATOR OF STUDENT'S INVOLVEMENT IN E-LEARNING SESSIONS

Shusaku Nomura
Nagaoka University of Technology
1603-1 Kamitomioka, Nagaoka, Niigata 940-2188, Japan
nomura@kjs.nagaokaut.ac.jp

Masako Hasegawa-Ohira
Nagaoka University of Technology
1603-1 Kamitomioka, Nagaoka, Niigata 940-2188, Japan
ohira@edu.shiga-u.ac.jp

Yoshimasa Kurosawa
Nagaoka University of Technology
1603-1 Kamitomioka, Nagaoka, Niigata 940-2188, Japan
s083364@stn.nagaokaut.ac.jp

Yasushi Hanasaka
Nagaoka University of Technology
1603-1 Kamitomioka, Nagaoka, Niigata 940-2188, Japan
s093366@stn.nagaokaut.ac.jp

Kuniaki Yajima
Sendai National College of Technology
4-16-1 Ayashi, Aoba, Sendai, Miyagi 989-3128, Japan
yajima@sendai-Nct.ac.jp

Yoshimi Fukumura
Nagaoka University of Technology
1603-1 Kamitomioka, Nagaoka, Niigata 940-2188, Japan
fukumura@oberon.nagaokaut.ac.jp

ABSTRACT

Objective evaluation of students' condition in e-learning sessions is analyzed in this study by introducing skin temperature information. With limitations of the use of conventional static behavioral information in

e-learning, e.g. progress logs and scores, a high demand on the quality assurance of course materials in e-learning is emphasized. In this study, the slightest change in the skin temperature of students who were engaged in e-learning materials was investigated, as past studies on stress have revealed that human behavioral change or coping style induced the change in the circulation of blood flowing, and which should result in the change in the skin temperature as well. In the experiment, the skin temperature of the students engaged in two contrasting e-learning exercises, i.e. interactive or non-interactive, were measured concurrently. As a result, the skin temperature showed significant decline when subjects were engaged in the interactive exercise, while there was no change in subjects engaged in the non-interactive exercise. The background knowledge and the results obtained through this study suggest that the decline in the skin temperature reflects the degree of concentration or involvement of the students. This in turn implies that the skin temperature can be a possible indicator of the student's involvement in e-learning sessions.

Keywords: E-Learning, Skin Temperature, Heart Rate Variability, Physiological Measurement

1. INTRODUCTION

Recent developments of e-learning systems give students the opportunity to learn at the time and place of their choice, resulting in a high demand in the quality assurance of course materials in e-learning is emphasized. In the ordinary lecture at a school, teachers can keep close watch on verbal and/or non-verbal reactions of the students, so it is easy to adjust or improve the material to be more understandable. In the e-learning system, by its virtue, the accessible information of the students is extremely limited to items such as access log, progress log, test record, chatting log, etc. Such statistical information would help to catch responses of students to some extent¹. However there is still wide gap between them in the manner of collection and evaluation of students' information.

On the other hand, a number of attempts have been made to detect human mental and somatic states by employing variety of physiological sensors². Brain wave (or electroencephalogram; EEG) and heart rate variability (HRV) have been frequently introduced to evaluate human psycho-physiological states, while other bio-electric signals, such as skin temperature³ and skin conductance (or electrodermal activity; EDA)⁴, are recently integrated into the list of physiological measures. However, only a

few attempts have been made to investigate such physiological responses of the attendees of e-learning courses⁵. Little is known about what types of learning materials induce what kind of physiological reactions on attendees or learners, and such an objective evaluation would provide useful information on the students' conditions such as proper participation of attendees.

In this study, a novel approach towards the evaluation of students in e-learning sessions is regarded; the physiological responses of the students who were engaged in e-learning materials were investigated. Amid a full battery of physiological signals, we focused on the skin temperature. Change in the skin temperature reflect changes in the blood stream, especially that of the peripheral blood stream. Moreover, a series of the past hemodynamic studies have revealed the close relationship between peripheral blood stream and “*the choice of behaviors*” of an individual under stressful conditions. Varieties of hemodynamic parameters, blood pressure, cardiac output, total peripheral resistance, etc, are known to change contrastingly by reflecting how he/she copes with a given stressors, e.g. taking a practical action (active coping) or just keeping in silence and withstanding the uncomfortable condition (passive coping)⁶. So, the choice of behaviors to cope with a stressful condition reflects the change in the circulation of blood flowing of the whole body. This implies that the skin temperature is expected to be changed by how he/she find and conduct a given e-learning materials, even though e-learning itself is not always considered as a “stressor”.

In this study we focused on the skin temperature changes in students in the context of two different e-learning materials to ascertain physiological states of the learners during distinct learning materials.

2. METHOD

2.1 Subjects

Thirteen male students, aged 19 to 20 years, voluntarily participated in this study. They were all Japanese technical college students and majoring in information science and technology.

2.2 Experiment Procedure

Figure 1 shows the schema of the experiment. The subjects were instructed to attend two e-learning course materials: a video lecture on advanced mathematics and a virtual laboratory work on electric circuit.

These two course materials were provided by a proprietary e-learning system in our institute. The lecture on advanced mathematics was video material of an ordinary instructor-led lecture in which a university professor delivers a lecture in front of a video camera, so it was characterized as a non-interactive material (*N-IM*). The other was virtual laboratory work on electric circuits in which attendees were required to perform a number of given tasks with a terminal PC, by its nature, it was characterized as an interactive material (*IM*). All subjects participated in both *N-IM* and *IM* conditions (within-subjects experiment). Each material took roughly about 25-35 minutes to complete.

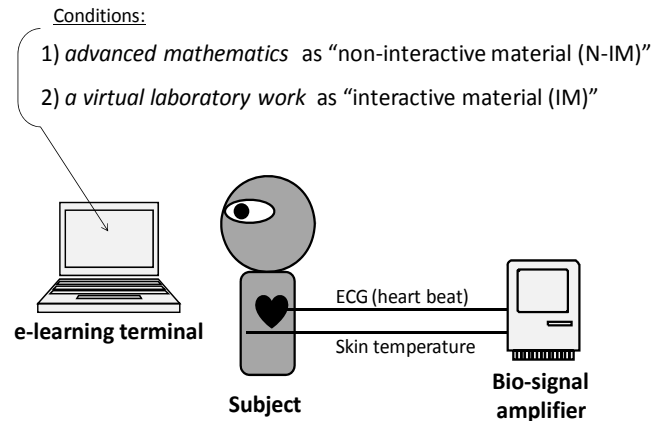


Figure 1. Schema of the experiment

2.3 Physiological Measurements and Data Analysis

Skin temperature was measured at the back of subjects' non-dominant hand using a thermistor probe (ITP082-25, NIKKISO-THERM Co., Ltd., Japan) and recorded by data logger at 1.0Hz of sampling rate. Electrocardiogram (ECG) was also recorded by bio-amplifier (BIOPAC MP150 systems, BIOPAC Systems Inc.) at 200Hz of sampling rate. Frequency analysis was performed on ECG data to calculate High Frequency (HF) (0.15-0.40Hz; HF) power of the signal. HF is considered to represent the parasympathetic nervous system activity⁷, therefore it can be taken as an index of subjects' “relaxing” or “resting state”. The collected physiological signals were segmented into every 60 seconds and averaged.

In the statistical analysis, *paired t-test* was performed in comparing the differences between the conditions, and *Wilcoxon signed-rank test* was also performed in comparing the difference within the condition in order to test if certain values increased or decreased throughout the experiment period.

3. RESULTS

3.1 Skin Temperature

Figure 2 shows the profile of the skin temperature in the time series in N-IM and IM condition. It should be noted that, for the better comparison, each trend in Figure 2 was baseline corrected, and all data was adjusted so that the initial value in each condition was set to the average valued for both N-IM and IM condition. The skin temperature was moderately decreased right after the experiment was started in IM condition, and subsequently dropped remarkably in the second half of the experiment period, while there was no change or even slight increment in N-IM condition. This pattern resulted in a significant difference of decline in IM condition for the whole period ($p < 0.05$) and the second half ($p < 0.05$) of the experiment. Meanwhile, there was no significant change in the skin temperature throughout the session in N-IM condition ($p > 0.05$), and this resulted in a significant difference between IM and N-IM conditions for the whole period ($p < 0.01$) and the second half ($p < 0.01$) of the experiment.

3.2 HF (Parasympathetic Nervous System Activity)

Figure 3 shows the HF profile in time series for N-IM and IM conditions. HF dropped immediately after the experiment was started in IM and N-IM conditions. There was no remarkable change in HF values between IM and N-IM conditions after the initial decline. However, the HF in both conditions stood below the baseline for the most period of the experiment. This pattern resulted in a significant decline in HF during both IM and N-IM conditions for the whole period ($p < 0.01$). In the meanwhile there were no significant difference between IM and N-IM conditions for the any time period of the experiment ($p > 0.05$).

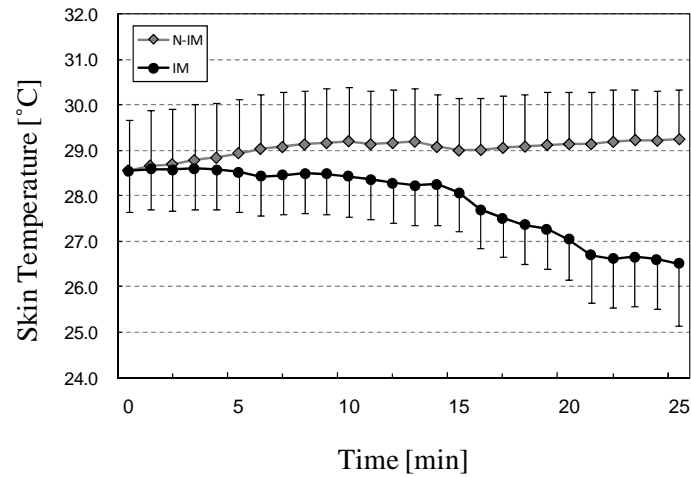


Figure 2. Skin temperature profile in the time series

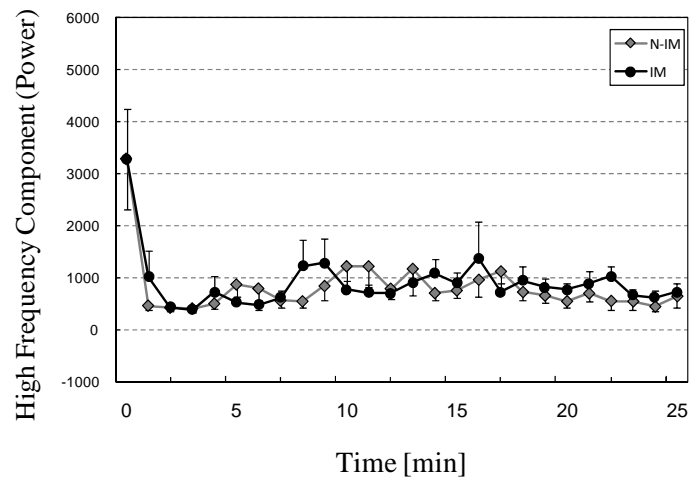


Figure 3. HF profile in the time series

4. DISCUSSION

The skin temperature showed significant difference in accordance with the contrasting e-learning materials implies a usefulness of this bio-signal to evaluate students' condition objectively. The decline of skin temperature, just as observed in IM condition in this study, has been reported in past psychophysiological studies focused on the mental workload^{8, 9, 10, 11}. Hioki et al. reported that the degree of decline of the skin temperature at top-tip of

nose was larger when the given mental workload was harder to perform⁹. In other words, the skin temperature shows a decline under the condition in which participants need to concentrate or make larger effort to perform a given task. Further, the decline of the skin temperature observed in IM condition in this study can be interpreted as subjects engaged in IM condition had deeply concentrated on or been involved in following the contents than that in N-IM condition, since there were not remarkable differences in the level of the two materials for the subjects who participated in this study.

Considering the characteristics of two materials employed in this experiment, the interpretation described above is reasonable. Since the material in N-IM condition is an unremarkable, video-recorded lecture, it can be assumed that such a non-interactive activity would require lesser effort to conduct in comparison to the IM condition in which subjects were required to perform a number of given tasks interactively.

On the contrary, HF values dropped drastically just after the start of both conditions and remained low for the whole period of both sessions, resulting no difference between both conditions. It is natural as numbers of past studies illustrated that HF can be a feasible index for “relax” and “rest”^{4, 12}. HF could be an index to show if a subject is *doing or not* but not how the subject is engaged, as illustrated in interactive or non-interactive materials. Contrastingly, considering that the skin temperature reflects the blood flowing and the blood flowing changes in accordance with “*the choice of behaviors*” against a stressful condition as described in the Introduction, the skin temperature would change to reflect higher cognitive functioning of the subjects; i.e. how he/she is engaged in the given task rather than just showing whether the subject is doing the task or not.

Overall, in this study the skin temperature is demonstrated to be affected by the characteristics of the given materials, whereas conventional heart rate variability is assumed to simply reflect subjects’ active/inactive state. This in turn implies that the skin temperature can be a possible indicator of the student’s involvement in e-learning sessions.

This study yielded very significant results nevertheless there were limitations. All thirteen subjects took part in this study were males. As the present study was conducted in a technical school, there was a scarcity of female subjects. In addition, the variety of learning materials used was limited because of the limitation of participation for this within-subject experimental design. In the e-learning stream, the learning contents are produced and delivered in a numerous forms such as the synergistic

virtual-space contents, online contents, offline contents and so forth. These limitations should be regarded in the future study.

5. CONCLUSION

In this study, we focused on the skin temperature changes in the students in the context of two contrasting e-learning materials to ascertain physiological states of the learners. As a result, the skin temperature showed significant decline when subjects were engaged in the interactive material, while there was no change in the non-interactive material. This study paves a new path for understanding students' condition objectively, which should be distinctively important for a future e-learning platform, as the insight into such physiological states in return may help in restructuring, improving and individualizing the learning materials, and to make e-learning more effective. Skin temperature can be also obtained by thermography. Moreover the thermistor employed in this study can be easily embedded and integrated into the mouse device, so it can provide totally non-invasive and stress free measurement. This study also suggests future inventions utilizing the skin temperature could be used in the e-learning platform.

This study was supported in part by Program to Disseminate Tenure Tracking System”, Promoting Science and Technology of the Ministry of Education, Culture, Sports, Science and Technology, Japan.

6. REFERENCES

- [1] J.M. Su, S.S. Tseng, W. Wang, J.F. Weng, J.T.D. Yang, and W.N. Tsai, Learning portfolio analysis and mining for SCORM compliant environment. *Educational Technology & Society*, 9(1), p262-275, 2006.
- [2] J.L. Andreassi, *Psychophysiology: human behavior & physiological response*, 5th ed. New York: Psychology Press, 2007.
- [3] A. Nozawa, and M. Uchida, characterization of preference for viscosity and fragrance of cosmetic emulsions by autonomous nervous system activity. *Presented at International Joint Conference of Institute of Control, Robotics and Systems and Society of Instrument and Control Engineers*, Fukuoka, Japan, August 18-21, 2009.
- [4] J.A. Healey, and R.W. Picard, Detecting stress during real-world driving tasks using physiological sensors. *Transactions of the Institute of Electrical and Electronics Engineers on Intelligent transportation systems*, 6(2), p156-166, 2005.
- [5] S. Scotti, M. Mauri, R. Barbieri, B. Jawad, S. Cerutti, L. Mainardi, E.N. Brown, and M.A. Villamira, Automatic quantitative evaluation of

- emotions in e-learning applications. *Presented at Engineering in Medicine & Biology Society of Institute of Electrical and Electronics Engineers*, New York, USA, August 29-30, 2006.
- [6] R.B. Williams, Patterns of Reactivity and Stress. In K.A. Matthews (Eds.), *Handbook of stress, reactivity, and cardiovascular disease* (p109-125). New Jersey: John Wiley & Sons, 1986.
 - [7] B. Pomeranz, R.J. Macaulay, M.A. Caudill, I. Kutz, D. Adam, D. Gordon, K.M. Kilborn, A.C. Barger, D.C. Shannon, R.J. Cohen, and H. Benson, Assessment of autonomic functions in human by heart rate spectral analysis. *American Journal of Physiology*, 248(1), p151-153, 1985.
 - [8] T. Mizuno, T. S. Nomura, A. Nozawa, H. Asano, and H. Ide, Evaluation of the effect of intermittent mental work-load by nasal skin temperature. *Transactions of Institute of Electric, Information, and Communication Engineers*, J-93D(4), p535-543, 2010.
 - [9] K. Hioki, A. Nozawa, T. Mizuno, and H. Ide, Physiological evaluation of mental workload in time pressure. *Transactions of Institute of Electrical Engineers of Japan on Electronics, Information and Systems*, 127(7), p1000-1006, 2007.
 - [10] A. Nozawa, S. Tomono, T. Mizuno, and H. Ide, Detection of fight or flight reaction on facial skin thermogram using spatio-temporal spectrum differential analysis. *Transactions of Institute of Electrical Engineers of Japan on Fundamentals and Materials*, 126(6), p470-477, 2006.
 - [11] H. Iwata, Quantitative evaluation of mental work by thermography. *Transactions of the Society of Instrument and Control Engineers*, 24(2), p107-111, 1988.
 - [12] G.F. Wilson, An analysis of mental workload in pilots during flight using multiple psychophysiological measures. *International Journal of Aviation Psychology*, 12(1), p3-18, 2001.

