Comparison of indices associated with skin conductance responses evaluating for emotional changes induced by tactile thermal stimuli

Kentaro Kotani(kotani@kansai-u.ac.jp)¹, Takafumi Shinoda(k402825@kansai-u.ac.jp)¹, Satoshi Suzuki(ssuzuki@kansai-u.ac.jp)¹, Takafumi Asao(asao@kansai-u.ac.jp)¹, Sigeyoshi Iizuka(shigeiizuka@gmail.com)²

¹Department of Mechanical Engineering, Kansai University, Osaka, Japan
²Faculty of Business Administration, Kanagawa University, Kanagawa, Japan

ABSTRACT

This paper presents empirical comparison among different indices related with skin conductance responses (SCRs) when human perceived thermal stimuli at the skin. Participants attached a probe in their right forearm for thermal stimuli, and SCR measurements were conducted when participants perceived the time to detect a temperature change. A total of four indices regarding SCR changes, i.e., response latency, time to peak, recovery time, and peak amplitude were obtained and analyzed to compare which of the indices showed high sensitivity with the changes induced by tactile thermal stimuli. The results showed that only the peak amplitude of SCR was significantly affected by the thermal gradients whereas other three variables, i.e., time to peak, response latency and recovery time failed to show any significant changes with the level of thermal stimuli. Peak amplitude observed for the condition of warm stimuli was higher than that for the condition of cold stimuli. Especially, peak amplitude observed at the 0.5 °C/sec of thermal gradients showed twice as large as that at the -0.5 °C/sec of thermal gradients.

Keywords: Emotion, Skin conductance responses, Thermal gradients, Tactile sensation.

1. Introduction

Thermal perception plays an important role in human activity (Doi, et al., 2012) and affects emotion, sentiment, and pleasantness (Akiyama, et al., 2013): thus, a communication device that has an effective interface with humans by using thermal perception is favorable (Nishimura, et al., 2014).

We have measured skin conductance responses (SCRs) developed by the automatic nerves system that is triggered by thermal stimuli (Shinoda, et al., 2016). A change in the SCR amplitude has been regarded as an objective index for emotional changes (Yamashiro, et al., 2004, Mizuno, et al., 2007, Sato et al., 2012). According to physiological studies (Ozawa, 2014), SCRs have been considered as an index for resulting in the sweat gland activity, which is controlled by the sympathetic nerves and becomes active when a human perceives a stimulus (Numata, et al., 2001, Miyata, 1998, Ikeura, et al., 1995). Thus, the emotion caused by thermal stimulation can be evaluated objectively.

SCR related-indices include the amplitude of the responses as well as response latency, recovery time, peak time, time constant and others. However, as far as we know, no other SCR-related indices than amplitude have been reported with regard to the changes in emotion induced by physiological and cognitive stimuli (Harrison, et al., 1999).

2. Method

2.1 Participants

The participants included 10 college students (with an average age of 22.2 years). All the participants were right handed. Each participant gave written informed consent prior to the beginning of the study.
2.2 Experimental apparatus and procedures

SCRs were measured using a portable bio-amplifier (Polymate, AP1000, NIHONSANTEKU Co., Japan) with an electrodermal activity (EDA) measurement unit (AP-U30m, NIHONSANTEKU Co., Japan). A thermal stimulator (Intercross-210, Intercross Co., Japan) was used for presenting thermal stimuli. Figure 1 shows the experimental setup used in this study.

The thermal gradient was set to 5 levels (−0.5, −0.3, 0, +0.3, +0.5 [°C/s]). Five measurements were performed for each thermal gradient, yielding 25 trials for each participant. After the practice session, the experiment was started by pre-adjusting the temperature at the probe and skin as an equal temperature. The temperature was then varied using a designated thermal gradient and participants pressed the button-switch as soon as they perceived the difference in temperature.

The detailed information regarding experimental setup and procedures referred to in the previous study (Shinoda, et al., 2016).

![Figure 1. Process of thermal perception and reaction. Participants were seated in a chair and covered with a headphone and an eye mask to minimize disturbance contaminated from auditory and visual information.](image1)

2.3 Data analysis

Independent variable was thermal gradients (four levels: (−0.5, −0.3, +0.3, +0.5 [°C/s])) and dependent variables were response latency, time to peak, recovery time, and peak amplitude of the SCRs. The onset of the awareness of changes in temperature was set to 2.2 [s] for the overall reaction time, considered using the study by Harrison et al., (1999), where the reaction time for the neural processing and reaction for the stimulus was estimated at 0.2 [s], and the distance between the area of stimulus presentation and the spinous process of the seventh cervical vertebra was estimated at approximately 1 [m]. Figure 2 illustrates the procedure where the participants noticed the thermal stimulation and press the button switch.

The existence of SCR amplitude was determined by referencing two preceding studies (Hata, et al., 2008, Hirot, et al., 2008). The detailed procedure can be found in our previous study (Shinoda et al. 2016).

![Figure 2. Process of thermal perception and reaction. It was estimated that participants react after 2.2 seconds from thermal stimulation was perceived. The detailed explanation can be found in Shinoda, et al., (2016).](image2)

3. Results and discussion

Figures 3 to 6 show the relationship between thermal gradients and four dependent variables, i.e., response latency, time to peak, recovery time, and peak amplitude of the SCRs. A significant difference on the peak amplitude was observed between thermal conditions (F(3, 55) = 4.65, p=.006), whereas no significant differences on the other three variables were observed (F(3, 55) = 0.55, NS for response latency, F(3, 55) = 1.86, NS for time to peak, and F(3, 55) = 0.82, NS for recovery time).

![Figure 3. Relationship between thermal gradients and response latency.](image3)
The results for the relationship between thermal gradients and peak amplitude implied that clear difference between tactile warm perception and cold perception affected the peak amplitude of SCRs. Peak amplitude shown at the 0.5 [°C/sec] of thermal gradients was twice as large as that at the -0.5 [°C/sec] of thermal gradients. SCR is an index for evaluating emotional sweating and emotional sweating response is closely related to the fight or flight system (Miyata, 1998). It is reasonable to say that heat perception induced rather feelings regarding emergent status, thus peak amplitude may be an index for the feeling of emergent status.

Molinari, et al. (1977) conducted an experiment to clarify the effects of the rate of temperature change using magnitude estimation and concluded that sensitivity to cool and warm stimuli did not vary with rate. However, the invariance between cool and warm stimuli may be due to the adaptation temperature for the coupling the skin and the Peltier stimulator. Their empirical results suggested an existence of accepted range of temperature that human felt secured. When adapting temperature was low, the accepted range of temperature lay the direction of high temperature more, thus the sensitivity of warm perception becomes low, whereas when adapting temperature was high, the secured margin of the temperature for warm perception is limited and the sensitivity of warm perception becomes high. Their study demonstrated the adapting temperature between 25 and 40 [°C] with -2.0 to 2.0 [°C/sec] of thermal gradients.

In our study, the adapting temperature was approximately 31 [°C] and hence, the secured margin stayed almost equally for both warm and cool perception. Thus changes between warm and cold stimuli to the peak amplitude of SCR obtained in our study did not seem to be influenced by the secured temperature. Further investigation should be required for clarifying the changes in peak amplitudes.

On the other hand, the rest of three indices i.e., response latency, time to peak, and recovery time of the SCRs may be biased by the adapting temperature although no significant differences were observed. Therefore, testing the changes in adapting temperature would be also included for further study to clarify whether these variables observed in SCR can be the potential index for the characteristics on thermal perception.
4. Conclusion

In our study, the results showed that only the peak amplitude of SCR was significantly affected by the thermal gradients whereas other three variables, i.e., time to peak, response latency and recovery time failed to show any significant changes with the level of thermal gradients. Peak amplitude observed for the condition of warm stimuli was higher than that for the condition of cold stimuli. Especially, peak amplitude observed at the 0.5°C/sec of thermal gradients showed twice as large as that at the -0.5°C/sec of thermal gradients.

SCRs has relatively slow temporal variation in nature, however the existence in signal fluctuation sometimes makes difficult to obtain noise-free values thus clear definitions for extracting informative indices from such signals should be established.

Acknowledgements

This study was partially supported by Private University Research Branding Project (2017) and by Environmental control based on human environment interaction research group, Kansai University.

References

Akiyama, S., Sato, K., Makino, T., Maeno, R., ThermOn—A Novel Thermo-musical Interface for an Enhanced Emotional Experience, Proceedings of Information Processing Society of Japan Interaction 2013, (pp.356-360), Tokyo. Japan. 2013.

Doi, K., Nishimura, T., Sea, A., Kusuhiyama, K., Babu, T., Sensory Characteristics of Temperature and its Discrimination in the Human Palm, International Journal of Affective Engineering, 11 (3), 419-425, 2012.

Harrison, J.L., Davis, K.D., Cold-evoked pain varies with skin type and cooling rate, a psychophysical study in humans, Pain, 83(2), 123-135, 1999.

Hata, T., A Trial for Quantitative Analysis of Electrodermal Activity by a “Lie-detector” Electrical Kit, Hamamatsu University School of Medicine Bulletin, Vol. 22, 2008

Hirota, A., Sawada, Y., Tanaka, G., Nagano, Y., Matsuda, I., Takasaki, N., A new index for psychophysiological detection of deception: Applicability of normalized pulse volume, Japanese Journal of Physiological Psychology and Psychophysiology, Vol. 21, No. 3, pp. 217-230, 2008

Ikeura, R., Ohtsuka, H., Inokoo, H., Study on emotional evaluation of robot motions based on galvanic skin reflex, The Japanese Journal of Ergonomics, 31(5), 355-358, 1995.

Miyata, Y., New Physiological Psychology Vol.1, Kitaooji Bookstore, 1998.

Mizuno, T., Norumura, S., Nozawa, A., Ide, E., Evaluation of Emotional Stress in Mental Workload, The institute Electronics information and communication engineers, IEICE Technical Report, pp.143-147, 2007.

Molinari, H., Greenspan, J.D., Kenshalo, D.R., The effects of rate of temperature change and adapting temperature on thermal sensitivity, Sensory Processes, 1, 354-362, 1977.

Nishimura, T., Doi, K., Karasawa, H., Sea, A., Relationship between Press Force and Sensory Characteristics of Temperature in Forefinger, International Journal of Affective Engineering, 13(3), 433-439, 2014.

Numata, K. Miyata, Y., Electrodermal Conditioning: Its Significance and Research Trends, The Journal of the Literary Association of Kwansei Gakuan University, 6(2), 55-88, 2001.

Ozawa, S., Standard Textbook of Physiology, IGAKU-SHOIN, 2014

Sato, K., Maeno, R., High-Response Thermal Display Unit using Spatially Distributed Warm and Cold Stimuli, Proceedings of Information Processing Society of Japan Interaction 2012, (pp.923-928), Tokyo. Japan. 2012.

Shinoda, T., Shimomura, K., Kotani, K., Suzuki, S., Asao, T., Iizuka, S., Empirical study of physiological characteristics accompanied by tactile thermal perception—Relationship between changes in thermal gradients and skin conductance responses—, HCI International 2016, Toronto, Canada, 2016.

Yamashiro, D., Aihara, M., Ono, C., Kanemura, H., Aoyagi, K., Goto, Y., Iwadare, Y., Nakazawa, S., Sympathetic Skin Response and Emotional Changes Visual Stimuli, No To Hattatsu, 36, 372-377, 2004.