博 士 論 文 の 内 容 の 要 旨

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論文題目	Study on evaluation method for clothing comfort sensation using psychophysiological measurement and its non-linear analysis （生理心理反応計測と非線形解析を用いた 着心地評価に関する研究）

（博士論文の内容の要旨）

Clothing comfort sensation is a complex combination of components, comprising physical, psychological, and physiological aspects. General linear analysis is not always sufficient for the evaluation of sensation. Rather, non-linear analysis methods (such as artificial neural networks [ANNs]), may be more appropriate than conventional linear analysis because the models are more similar to the structure of the human brain and exhibit flexible computing ability. The purpose of the current thesis was to verify the effectiveness of an evaluation method for clothing comfort sensation via numerical analysis using an ANN through measuring psychophysiological responses. In this thesis, a wide range of material properties of undershirts and wearers' physiological and psychological responses were measured to evaluate clothing comfort sensation using numerical analysis.

As a first step toward achieving this purpose, in Chapter 2, a conventional linear analysis method was tested. Although previous studies confirmed the existence of relationships among clothing comfort sensations and other psychological sensations and physiological indices, the stimulation conditions of the fabric samples within these studies have been simplistic and highly variable. Thus, the effectiveness of measuring and evaluating physiological responses for undershirts with similar properties remains to be fully clarified. In the experiment described in Chapter 2, the psychophysiological responses were measured while participants wore two types of undershirts with minute differences in material properties. Undershirts were prepared using the same hydrophobic fiber materials with other similar material properties, namely polyester (polyethylene terephthalate [PET]) and polypropylene (PP). The results revealed that the ratio of low-frequency and high-frequency index (LF/HF) calculated from electrocardiogram recordings exhibited a strong negative correlation with clothing comfort sensation before and after exercise. This finding indicated that the LF/HF was able to estimate discomfort during perspiration caused by exercise. However, there was no significant difference between the fabric samples. In addition, wearers discriminated differences in sensations of coolness and stuffiness between the fabric samples caused by minute differences in thermal and moisture transport properties. The differences in the sensation of stuffiness between the fabric samples were consistent with the coefficient of variance of the R-R interval (CVRR) obtained from the electrocardiogram. Thus, the CVRR can be used to evaluate thermal discomfort sensations such as stuffiness. In addition, psychophysiological measurements and conventional linear analysis can be applied for the evaluation of clothing comfort sensation, even between clothing constructed from materials with minute differences. However, CVRR and the sensation of stuffiness did not exhibit a strong linear relationship. The results reported in Chapter 2 also indicated that non-linear analysis may be more suitable for the evaluation of complex psychological factors.

In Chapter 3, psychophysiological measurement was performed. The purpose of this measurement was to collect the data required for the ANN analysis conducted in Chapter 4. Three types of undershirts with different material properties were constructed using hydrophilic fibers (cotton or rayon) and hydrophobic fibers (PP) to create a state in which the human condition changes variously in an environment where sweating occurs. The psychological structures of clothing comfort sensations were analyzed while the clothing samples were worn. Multiple regression analysis was used to analyze the psychological structure of the clothing comfort sensation for each sample, revealing that the psychological factors of the clothing

comfort sensation varied depending on the material characteristics of each sample. For the PP blended samples, which have better moisture-transport and air permeability properties, sensations related to thermal comfort properties affected the clothing comfort sensation. In addition, the sensation of softness exerted a strong influence in the 100% cotton sample condition, which had high thickness and soft compression properties. The psychological structure was confirmed before analysis using ANN.

Finally, in Chapter 4, the evaluation method using ANN was verified with data obtained from the psychophysiological responses in Chapter 3. The purpose of Chapter 4 was to verify the effectiveness of the evaluation method for the clothing comfort sensation using ANN. The relationships between three input conditions were investigated: (1) physiological responses only; (2) psychological responses only; and (3) both psychological and physiological responses. The experiment revealed that it was possible to predict sensation with an accuracy of up to 85% when using data of both physiological and psychological responses as input values. The results indicated that measuring and using both subjective psychological sensation and objective physiological response data is important for the evaluation of clothing comfort sensation. Furthermore, the prediction accuracy of conventional linear analysis using multiple regression analysis was compared with the accuracy of the ANN method. The results revealed that the coefficient of determination (R^2) of the ANN had a higher value and lower mean absolute error. It indicated that ANN analysis was more accurate. Therefore, the results suggested that the method using ANNs with psychological sensation and physiological response data was effective for the evaluation of clothing comfort sensation.

Through the series of experiments presented in this thesis, the effectiveness of the assessment method was verified for evaluation of clothing comfort sensation using ANNs. Additionally, the importance of measuring both physiological responses and psychological sensations was confirmed. These findings will contribute to the development of more accurate evaluation models for clothing comfort sensation in future. Additionally, the present results will be useful for informing future studies establishing better tools for analyzing the complex relationships between clothing comfort sensation and other input indices using the non-linear computing ability of ANNs.