博 士 論 文 の 内 容 の 要 旨

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論文題目	Study on relaxation induction by multisensory stimulation based on thermal stimulation by measuring physiological responses **(生理反応計測による温熱刺激をベースとした多感覚統合による リラックス誘導に関する研究)**

(博士論文の内容の要旨)

This study aims to examine to the relaxation-inducing effects of multisensory stimulation based on thermal stimulation using physiological response measurement. Recently, next-generation smart homes and self-driving cars become widespread, and it is expected that comfort in the indoor environment will become more important. In spaces where people spend a long time, such as homes and in-vehicle environments, the development of methods for inducing a state of relaxation is important for providing comfort in daily life. The relaxed state targeted in this study is a comfortable state such as just before falling asleep in the absence of unpleasant factors. In a relaxed state, parasympathetic nervous are activated and brain activity is suppressed. The current study aimed to identify a method of stimulus presentation to positively induce physiological and psychological relaxation states. Clarifying a stimulus presentation method for inducing a relaxed state in humans may inform approaches for designing highly comfortable interior environments. Here, this study focused on multisensory integration as a method of inducing a high relaxed state.

The relaxation-inducing effect of multisensory integration has been reported in previous studies. However, the optimal combinations of stimuli for most effectively inducing relaxation have not been clarified. While many combinations of stimuli are expected, this study targeted multiple sensory integration based on thermal stimulus to the soles of foot. Thermal comfort is a fundamental and important factor in the indoor environment, additionally, the sole of the foot is a peripheral part that constantly conducts heat with the outside world in daily life in both the standing and sitting positions. In real-world situations, thermal stimuli are often experienced simultaneously with stimuli in other sensory modalities. The current study examined the effects of simultaneous thermal stimulation of the feet with stimuli targeting other sensory modalities, including sound (music), light (movie and illumination), odor, and vibration (applied to the trunk). These stimuli were intended to induce relaxed state and can be implemented in the interior / in-vehicle environment in the future. The stimuli presented in the experiment were selected from multiple comfort-related stimulus candidates for each sensory organ as the stimuli with strong relaxing effect (Chapter 3). The relaxation-inducing effect of multisensory integration was evaluated by measuring the physiological and psychological responses (Chapter 4).

Chapter 2 reports the measurement method of the physiological response of the autonomic nervous system and central nervous system and the physiological indices related to relaxing state. Electrocardiogram, respiration, fingertip pulse wave, sweating, peripheral blood flow, electroencephalogram and cerebral blood flow in the prefrontal cortex were measured, and 11 types of physiological indicators were calculated from these biological signals. Time-series physiological responses during stimulus presentation were measured, and changes in physiological state induced by each combination of stimuli were evaluated.

In Chapter 3, Scheffe's paired comparison method (Ura's variation, odor stimuli were evaluated using Nakaya's variation) was conducted to identify the most relaxing stimuli

for each sensory modality. The selected stimuli are as follows: thermal stimulus to the sole of the foot at 40 ℃, movie showing an underwater scene, classical piano music, light blue illumination, vibration to trunk with frequency of 55Hz, and grapefruit odor.

In Chapter 4, the relaxation-inducing effects of simultaneously presenting thermal stimulation and that of other sensory organs was examined using physiological responses measurements and sensory test. The experiment was carried out in a room with constant temperature and humidity (25° C, 55% relative humidity). The results revealed that all stimulus combinations enhanced parasympathetic activity and suppressed brain activity, indicating relaxed state. As for the subjective evaluation, all combinations of stimuli improved the feelings of comfort and feelings of relaxation, and decreased the arousal level. In addition, “music + thermal” combination tended to be evaluated higher than other stimuli among stimuli. Additionally, the relaxation-inducing effects of thermal stimuli plus stimuli targeted at other sensory organs was characterized, as well as the differences in the latency and duration of the physiological responses to each stimulus. In particular, the “odor + thermal” combination significantly induced relaxation, and the latency of physiological responses was relatively long. The “music + thermal” combination induced relaxation in a short period of time. Moreover, the “movie + thermal” combination induced relaxation and was characterized in that the latency of the physiological response differs depending on the physiological indices.

The presented stimuli could be classified into (1) cognitive stimuli (movie / music / illumination) and (2) stimuli that directly act on the body (thermal/ odor/ vibration). Focusing on the difference in each physiological index between the stimuli during the presentation of the stimulus, the combination of the thermal stimulus and the stimulus in category (2) significantly enhanced parasympathetic nervous system activity and suppressed brain activity compared with other stimulus combinations. This result suggests that the combination of stimuli that act directly on the body has a strong effect of inducing relaxation by multisensory integration involving thermal stimulation.

In conclusion, relaxation-inducing effects by multisensory stimulation based on thermal stimulus was verified. Additionally, the difference in latency and duration of physiological responses depending on the combination of stimuli were confirmed. The current findings suggest possible approaches for promoting relaxation in humans through the design of high-comfort indoor and in-vehicle spaces. This study was limited to a combination of two stimuli based on thermal stimulation. Future research on multisensory integration is expected to verify the relaxing effects of matching impressions between stimuli and presenting stimuli within a stimulus category.