人間科学研究　Vol.36, No.2, Supplement（2023）

濡れおよび蒸れ知覚に関わる神経基盤の探索

Research on The Neural Basis of Wet and Humid Sensations

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Introduction Thermoregulation is one of basic functions in sustaining homeostasis. Maintaining core body temperature in mhomotherms is achieved by behavioral and autonomic thermoregulation mechanisms. Sensing the surrounding environment conditions is crucial in thermoregulation. Environmental temperature, humidity, and air flow are important factors that affect thermoregulation. Sensing the humidity of the environment and wetness on the skin surface to alter the surrounding environment is also crucial in thermoregulation. Despite extensive research, the mechanisms underlying humid and wet sensation in humans are poorly understood. Identifying these mechanisms could have important implications for understanding thermoregulation.

Aim and Hypotheses The aim of the present study is to investigate the mechanisms of the formation of the wet and humid sensation and to identify the neural bases involved in these sensation. It is clear that tactile and thermal stimuli are necessary for forming the sensation of moisture. However, the contribution of these two stimuli to wetting sensation and the neural basis of sensation formation remains unclear. Therefore, in this study, the Aim 1 is to explore the mechanism of sensory formation related to the sensation of environmental humidity. Then, as Aim 2, we aim to clarify the contribution of mechanoreceptors and thermoreceptors to the wet sensation by mechanical stimulation. In this study, the following two hypotheses were tested.

1) The perception of steaminess is vital for thermal sensation in the nasal mucosal cavity. In addition, the temperature change on the nasal mucosa due to moist conditions of inhalation enables the perception of the humidity of the environment. As a result, we hypothesized that wearing a mask would elevate the humid sensation and increase physical and psychological fatigue.

2) Wet sensation is determined by tactile and temperature sensations, as previously hypothesized. In addition, we hypothesized that even if the temperature is constant, an increase in the moisture content of the touched material increases the wet sensation and that the intensity of the wet sensation is modified and altered by the temperature sensation.

Experiment I (Chapter FOUR)

[Purpose] This Experiment aimed to investigate whether wearing a face mask in a high temperature and high humidity environment affects the humid sensation, the thermal sensation, and the thermoregulatory function. **[Methods]** Twelve participants conducted treadmill exercise for 30 min at 6 km/h, with 5% slope, 35°C ambient temperature, and 65% relative humidity, while wearing or not a surgical mask (mask and control trials, respectively). Rectal temperature (T_{rec}), ear canal temperature (T_{ear}), and mean skin temperature (mean T_{skin}) were assessed. Skin temperature and humidity of the perioral area of the face (T_{face} and RH_{face}) were also estimated. Thermal sensation and discomfort, sensation of humidity, fatigue, and thirst were rated using the visual analog scale. **[Results and Discussion]** T_{rec}, T_{ear}, mean T_{skin}, and T_{face} increased during the exercise, without any difference between the two trials. RH_{face} during the exercise was greater in the mask trial. Hot sensation was greater in the mask trial, but no influence on fatigue and thirst was found. These results suggest that wearing a surgical mask does not increase the risk of heat stroke during mild exercise in moist heat.

Experiment II (Chapter FIVE)

[Purpose] This Experiment aimed to examine how wet perception changes when the factors related to thermal and/or wetness stimuli are modulated. **[Methods]** First, the percentage of participants experiencing wet perception among filter papers with different water contents (0.00, 3.75, 7.50, 11.25, 15.00, and 18.75 $\mu g/cm^2$, corresponding to 0.00, 0.18, 0.37, 0.55,0.73 and 0.91 $\mu g/mm^3$) was evaluated during static touch by the right index finger pad. The stimulus temperature was maintained at 30°C. Second, the wet perception of paper with a water content of 18.75 $\mu g/cm^2$ was evaluated at stimulus temperature of 20°C, 25°C, 30°C, 35°C, and 40°C. **[Results and Discussion]** In the first experiment, the percentage of participants experiencing wet perception elevated with the increasing water content; however, the percentage plateaued at 11.25 $\mu g/cm^2$ of water (68.1±25.5%). In the second experiment, when the stimulus temperature was≧30°C, the wet perception increased as the stimulation temperature decreased. However, the wet perception reached a plateau at a stimulation temperature≥30°C. Participants experienced wet perception more consistently as the water content increased when the stimulus temperature was 30°C. The effect of temperature on wet perception was limited to the stimulus temperature of＜30°C at which cold sensation was induced. However, no clear relationship between stimulus temperature and wet perception was observed when the stimulus temperature was≥30°C at which warm/hot sensation was induced.

General Discussion and Conclusion

This study investigated the factors contributing to humans' humid and wet sensation. The new findings add to previous studies on the relationship between wetting sensation and thermal sensation (especially warm sensation). Study 1 examined the impact of wearing a face mask on the humid sensation, thermal sensation, and thermoregulation. Study 2 focused on the effects of mechanical and thermal stimuli on wet perception.

In study 1 (Chapter Four), it is noteworthy that there was no change in core body temperature or skin temperature. Based on these results, the expansion of humid and thermal sensation on face and thermal sensation on the whole body in Study 1 are due to increased local humidity on the face. Since the change in relative humidity significantly influences temperature changes on the mucosa, this property is expected to play a role in the nasal cavity's function as a humidity sensor. These studies also indicate that the nasal cavity is suggested to be involved in the humidity-sensing function. Study 2 (Chapter Five) showed that subjects could sense differences in minute amounts of water (3.75 $\mu l/cm^2$) at their fingertips. This result is a tiny amount of stimulus compared to the perceived threshold for moisture shown in previous studies. Furthermore, the results suggest that this wet sensation is enhanced by cold sensation but is not affected by warm sensation. These results suggest that wet sensation is not a simple effect of temperature but is expected to have an independent relationship with cold sensation. The results of Study 1 and Study 2 suggest that TRPM8, a cold-sensing receptor molecule, may be an essential factor in the pathway of perception of moisture. Future studies will explore the detailed mechanisms of cold sensation's involvement in wet sensation and clear the neural circuits, neural substrates, and central regions responsible for wetness.

This study investigated the mechanisms involved in forming wet and humid sensation. Here we conclude the following about the mechanisms of humid and wet sensation.

i) The increase in local humidity on the face enhances thermal sensation and humid sensation on the face. As a mechanism for this, it was concluded that the change in local humidity in the nasal cavity caused by breathing changes thermal sensation, which in turn causes an increase in humid sensation.

ii) Wet sensation is caused by mechanical stimuli independent of thermal sensation, and minute changes in water content are perceived. Furthermore, wet sensation is enhanced by an increase in cold sensation, whereas warm sensation does not affect the magnitude of wet sensation.