MOISTURE EVAPORATION FROM EYES AND PREVENTION OF SENSATION OF DRYNESS UNDER LOW INDOOR HUMIDITY

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Purpose

To create an indoor thermal environment with no sensation of dryness, it is necessary to control the indoor temperature, humidity, and air flow. Under low humidity conditions, occupants sometimes complain of a sensation of dryness at the throat, eyes, and skin [1]. It is therefore necessary to quantify moisture evaporation from the surface of the body and to identify an optimum method of control for the indoor environment [2, 3, 4]. The minimum humidity level for an acceptable thermal environment has never been clarified, though it is known that low humidity may cause skin drying, irritation of the mucous membranes, and dryness of the eyes [5]. In this study, the eyes were focused on, and the evaporation rate at the eyes was studied experimentally. It is difficult to measure the evaporation rate at the eye surface directly. The surface temperature of the eye was therefore measured using radiation thermometers, and the correlation between the surface temperature and the blink rate as an indicator of the condition of the eye was studied for the basis of the quantitative estimates of the evaporation rate of tear.

Method

Two kinds of subject experiments were conducted. In both, the ocular surface temperature and the blink rate were measured using contactless methods. In the first experiment, 100 university students were recruited as subjects. The surface temperatures of the eyes and face and the blink rate were measured in a standard room in the university, at 21 ºC and 50%rh. The surface temperature was measured using an infrared camera (Avio, TVS-700), and the blink rate was determined from a video recording. In the second experiment, two subjects (university students) were tracked for periods of 130 min per day in an artificial climate chamber for three days, and the temperature and the blink rate were measured as the environment was varied from 23-35 ºC and 40-50%rh. The ocular surface temperature was measured using a radiation thermometer (Japan Sensor TNH91S-L500N5S3A), and the blink rate was measured by a blink counter (Takei Scientific Instruments S-13044).

Results

Experiment 1 (Measurement of a moment for 100 subjects)

The results are summarized in Table 1. The ocular surface temperature was 33.7 ºC on average. The ocular surface temperatures of subjects not wearing contact lenses were 0.5 ºC higher than those of subjects wearing contact lenses, whereas the skin temperature at the face did not differ. The blink rate of subjects not wearing contact lenses was lower. As shown in Figure 1, the ocular surface temperature was negatively correlated with the blink rate.

Table 1: Results of Experiment 1 (Measurement of a moment for 100 subjects)

		All subjects	Without contact lens	With contact lens
Ocular surface temp. [ºC]	Ave.	33.7	34.0	33.5
	S.D.	0.67	0.46	0.72
	Max.	35.3	35.3	34.8
	Min.	31.9	32.9	31.9
Skin temp. at face [ºC]	Ave.	33.1	33.2	33.0
	S.D.	0.71	0.65	0.76
	Max.	34.7	34.3	34.7
	Min.	31.2	31.3	31.2
Blink rate [times/min]	Ave.	18.6	15.3	21.3
	S.D.	12.9	10.7	14.0
	Max.	64	45	64
	Min.	1	3	1
Number of data		100	46	54

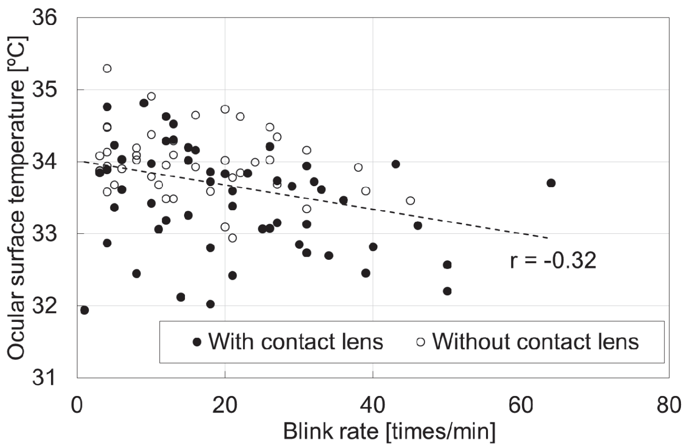
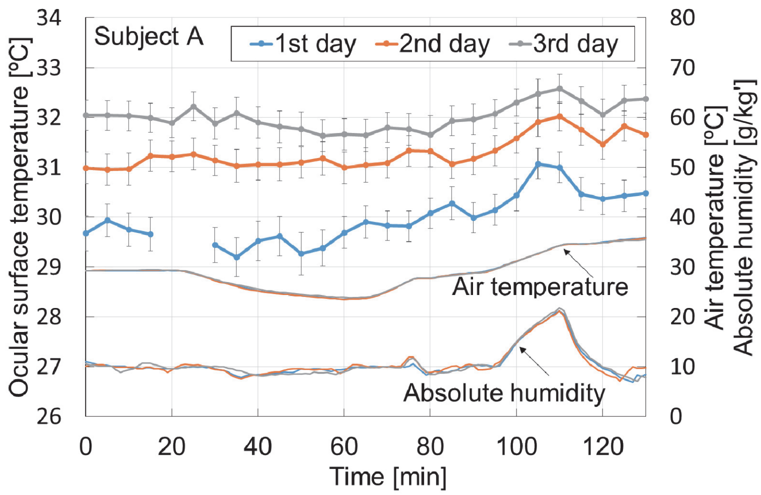


Fig. 1: Relationship between blink rate and ocular surface temperature (Experiment 1, n=100, room air temperature 21.3 ± 2.8 ºC, room air relative humidity 49 ± 9%)

Experiment 2 (Measurements repeated three times for two subjects)

As shown in Figure 2, the ocular surface temperatures of both subjects varied day by day although the subjects were exposed to almost the same conditions of the thermal environment. The ocular surface temperature followed the room air temperature, while the blink rate fluctuated independently of the room air temperature. Taking the average values for one day, the ocular surface temperature was negatively correlated with the blink rate, as shown in Figure 3.



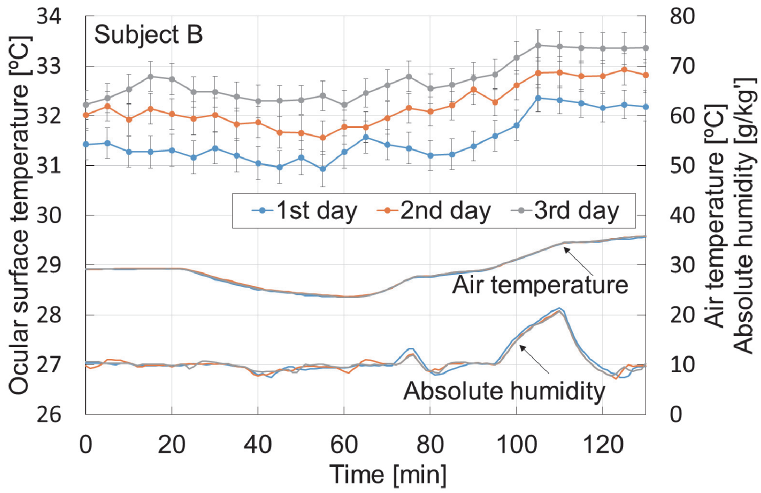


Fig. 2: Results of Experiment 2 (Measurements repeated three times fortwo2 subjects, Subject A wore contact lenses, and Subject B did not)

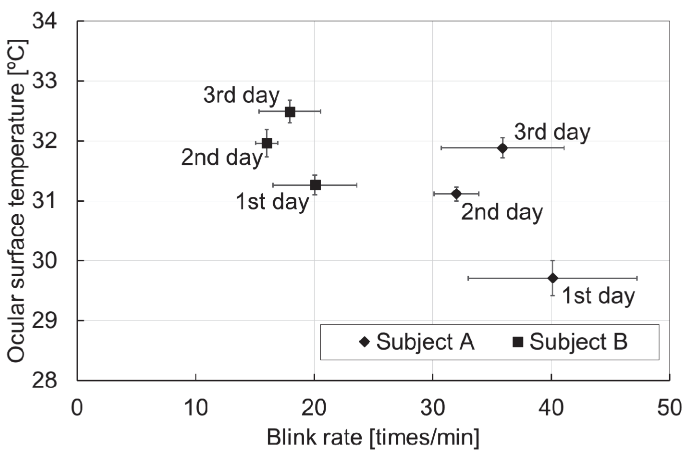


Fig. 3: Relationship between blink rate and ocular surface temperature (Experiment 2, Average and S.D. are shown)

Discussion

The ocular surface temperature is determined by the heat balance, in which the evaporation rate of moisture is one element. If the body and ambient temperatures are the same, a difference in the ocular surface temperature should reflect the difference in the evaporation rate. Ophthalmology has shown that blinking prevents evaporation from the ocular surface by forming an oil layer at the outer surface of the tears [6, 7, 8]. An increase in blink rate may therefore reflect the condition of the tear film on the eye. In Experiment 1, the ocular surface temperature was negatively correlated with the blink rate. This suggests that a high blink rate is associated with a high evaporation rate, and thus with a low ocular surface temperature. This could also explain the results from Experiment 2, both for the three day data on one subject, and for the entire data set. However, the correlation coefficients shown in Figures 1 and 3 were not high, and confirmation is therefore necessary through further experiments. Experiment 1 focused on between-subjects difference, whereas Experiment 2 also focused on within-subjects differences. The results of this study suggest that both inter- and intra-individual variations may arise in the conditions of tears, and that it could affect the ocular surface temperature.

Acknowledgements

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