Development of a Glasses-Like Wearable Device to Measure Nasal Skin Temperature

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Abstract. Since nasal skin temperature is said to provide a good reflection of autonomic nerve activity, nasal skin temperature measurements have been used to assess various human physiological and psychological states, such as pleasant and unpleasant emotions, alertness levels, and mental work load (MWL). In addition, nasal skin temperature has the advantage of enabling non-contact measurement, using such as thermography and radiation thermometers.However, a problem exists with approaches using these device because it is difficult to make accurate assessments if the test subject moves during measurement.

This study aims at resolving this problem via the development of a wearable device that measures nasal skin temperature with small thermopile sensors attached to spectacle frames, thus enabling temperature measurements even when the wearer moves.

Keywords: Nasal skin temperature · Autonomic nerve activity · Wearable device

1 Introduction

Since autonomic nerve activity is closely related to physical and physiological stress, its measurement or estimation using biological information can serve as the foundation for methods of objectively assessing bodily activity or physical and physiological stress in human beings.

One such method, which uses body surface temperature [1,2] is based on the knowledge that the body surface temperature of humans depends on the blood flow rate through the blood vessels below the skin. When muscle contraction and relaxation occur as a result of autonomic nerve activity, the blood flow rate through the capillaries close to the body surface changes, and large amounts of blood flow into arteriovenous anastomoses (AVAs). Since the area around the nose has a substantially higher distribution of AVAs than other parts, autonomic nerve activity changes have a particularly strong influence on the surface temperature of the nose. Specifically, it can be observed that when the activity

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of sympathetic nervous system of the autonomic nervous system increases, the surface temperature of the nose decreases. It then follows that monitoring nasal skin temperature makes it possible to indirectly assess autonomic nerve activity.

However, nasal skin temperature is dependent on an individual's deep body temperature and the measurement environment. If the deep body temperature or measurement environment changes while nasal skin temperature is being monitored, the resulting noise and artifacts decrease the assessment accuracy. One method of countering this problem is to use the difference in body surface temperature between the nose and the forehead. Since the density of AVAs in the forehead is low, body surface temperature in this area is less susceptible to changes resulting from autonomic nerve activity. Therefore, subtracting the forehead surface temperature from the nose surface temperature reduces the influence of deep body temperature and/or measurement environment changes.

Since using the patterns of change in autonomic nerve activity obtained with this method as feedback allows for the possibility of, for example, reducing human error, adverse health effects, or stress, a wide range of studies are currently being conducted.

In an earlier study, assessments of human physiological and psychological states, such as pleasant and unpleasant emotions, degree of alertness, and mental work load (MWL) were conducted [3]. Low-restraint, non-contact measurement of nasal skin temperature can be performed using approaches such as thermography and radiation thermometers, but the measurement environment imposes limitations. For example, it is difficult to make assessments if the test subject moves during the measurement.

In an attempt to resolve this problem, we developed a glasses-like wearable device to measure nasal skin temperature that allows autonomic nerve activity to be measured or estimated even if the test subject moves. In this report, we aim to verify the reliability of measurement with this device.

2 The Developed Device

Figure 1 shows a facial thermal image of a test subject while under an MWL imposed by mentally performing arithmetic calculation tasks.As can be seen in the figure, a temperature difference between nose and forehead is evident. In an earlier study, the mean surface temperatures of the nose and forehead regions were obtained using infrared thermography, as shown in Fig. 1, and this temperature difference was used for assessment. Figures 2 and 3 show a diagram of our newly developed glasses-like wearable nasal skin temperature measurement device and a photo of its appearance when worn.

In this study, these body surface temperatures of the nose and forehead were obtained using small, high-accuracy, thermopile sensor modules (HTIA-E, Heimann Sensor GmbH, Dresden, Germany) attached to the spectacle frames. The sensors operate at a source voltage of 5 V, provide a viewing angle of 10°, have a measurable temperature range of 30 ° to 500 ° C, and a accuracy of approximately ±0.1 ° C.

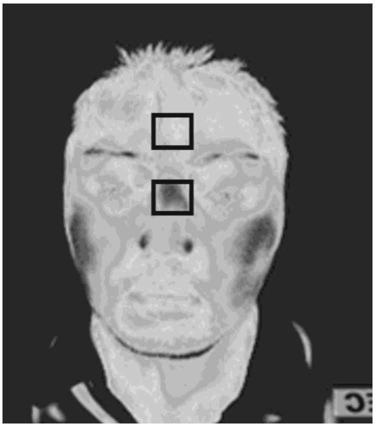

Fig. 1. A facial thermal image of a test subject while under an MWL

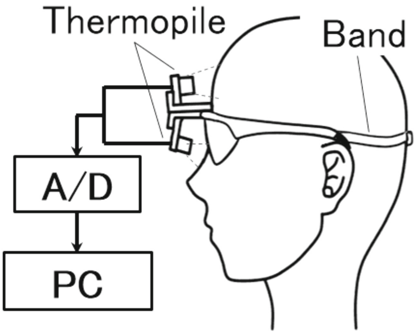

Fig. 2. Developed glasses-like wearable nasal skin temperature measurement device

Furthermore, the modules used are light, weighing 1.07 g, so wearing the device feels much like wearing ordinary glasses. Thus, the design of the device enables simultaneous low-restraint, non-contact measurement of nose and forehead surface temperatures. The thermopile outputs are received on a personal computer (PC) via an analog-to-digital (AD) converter (Turtle Industry Co. Ltd., TUSB-0216ADMZ). The sampling frequency is 250 Hz and the mean value of the body surface temperature measurements is recorded each second.

3 Verification Experiment

3.1 Aim of Experiment and Experimental Protocol

The following experiment was conducted to verify whether changes in nasal skin temperature could be assessed with the developed device when a test subject is under an MWL.

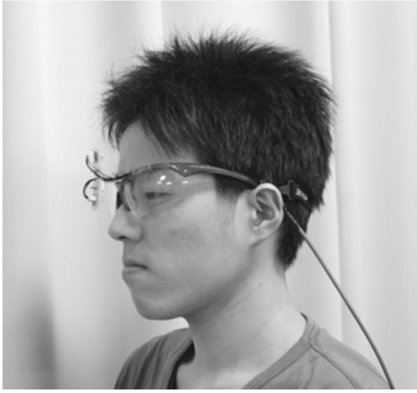

Fig. 3. State of wearing the glasses

In our experiment, five 22-year-old test subjects in good health were tasked with performing mental arithmetic calculations in order to impose an MWL. Specifically, they were asked to solve two-digit numbers addition problems displayed on a PC. They were given three seconds for each problem, after which the next problem appeared, regardless of whether or not their answer was correct. After the test subjects relaxed for a few minutes in a seated position, measurement commenced with three minutes of rest, followed by three minutes of mental arithmetic calculation tasks, and then three minutes of rest, at the end of which measurement was stopped. The total length of the experiment was 9 min.

3.2 Experiment Results and Discussion

The results are shown in Fig. 3. During the initial rest period various minor fluctuation were recorded, but a drop in temperature was noted for several test subjects during the initial calculation task period. In those cases, the temperature returned to its original value during the following rest period. These results indicate that the mental arithmetic calculation task imposed an MWL burden on those test subjects, which influenced their autonomic nerve system responses.

However, despite being tested under the same protocol, not all test subjects exhibited the above temperature change. There are several possible reasons for this, which are outlined below (Fig. 4):

1. The mental arithmetic calculation tasks did not impose a noticeable MWL burden on those test subjects, so their autonomic nerve systems were not influenced.
2. For some test subjects, differences in the distance from the thermopiles attached to the glasses and the nose or forehead caused by head or face shape variations prevented appropriate measurements.
3. There were individual differences between the locations where temperature change occurred.

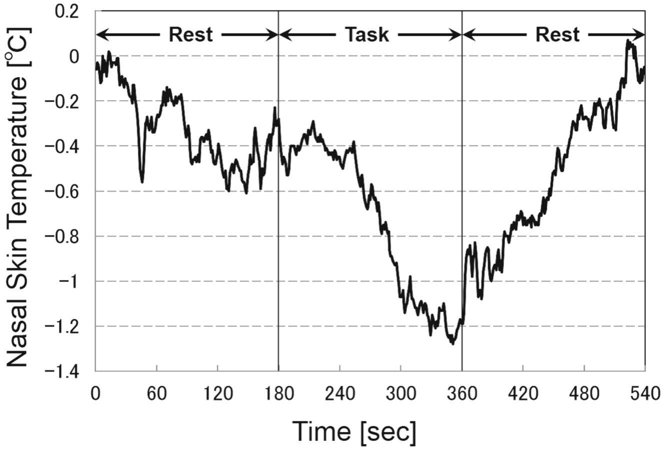

Fig. 4. Result

To investigate the first hypothesis, it will be necessary to impose a variety of tasks. The second and third hypotheses stem from the fact that the thermopiles used have a narrow viewing angle. Since the current attachment position is about 6 mm in diameter, the temperature is measured as the mean temperature of a very small area. The results of the earlier study (Fig. 1) suggest that a diameter of around 2 to 3 cm is necessary to ensure reliable mean temperature assessments. In our future studies, it will be necessary to solve this problem by adjusting the distance between the thermopiles and the nose and forehead of the test subjects.

4 Conclusion

In this study, a glasses-like wearable device that can be used to measure nasal skin temperature was developed and its reliability was assessed. The results show that the device makes it possible to estimate autonomic nerve activity. This has the potential to pave the way for everyday applications such as routine monitoring (life-log) of autonomic nerve activity.

However, autonomic nerve activity cannot be assessed in some cases due to the shape of the test subjects head or to the positioning of the device. Therefore, in our future studies it will be necessary to facilitate sensor position and angle adjustments in order to improve lightness and accuracy. It will also be necessary to utilize a structure that does not impede the view, and to conduct comparison experiments using a technique such as infrared thermography.

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