Extraction of Unconscious Perceptual Information Using Blood Flow Measurement in Face by General Purpose Camera

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ABSTRACT

We are developing a method for estimating the load state of human. The method uses signals of facial blood flow changes measured by using a general purpose RGB camera.

1 INTRODUCTION

In recent years, for the diversification of the working style, the development of a remote work support system that can collaborate while the worker trained are in different places is expected. They need to know the load state of a worker even remotely. A subjectivity evaluation using a questionnaire is a general method to obtain information about fatigue and the health condition. However, the establishment of the technique to measure objectively is expected because we can hide our state by the subjectivity evaluation.

An activity of the autonomic nervous system is one of the physical reaction that human cannot feign intentionally [1]. We can not change it intentionally, because this activity is the involuntary activity that the body shows automatically depending on states and environment of human. In addition, the skin blood flow is known to change by the function of autonomic nerve. For example, it is performed by controlling blood flows of capillary and the arteriovenous anastomoses (AVA) with autonomic nerve when human regulates a body temperature [2]. AVA has thickness of about 10 times of the capillary and blood flows of 10, 000 times. Human release the heat of the body outside by extending AVA very much when caloric adjustment is short by the blood flow of the capillary[3]. Blood flows remarkably changes by the reaction of AVA when human receives the stimulation. We can detect a reaction of AVA from the changes of the blood flows of the capillary, because the blood flows change of the arteriolovenular anastomosis links capillary.

In this study, we estimate the states of the work from the image of a worker measured by using a general-purpose camera (typical RGB camera) to measure the change in the amount of skin blood flow. The changes of the blood flow in the face can be measured by non-contact, and an external stimulus can be estimated by measuring the changes in the autonomic nervous [4]. The change of unconscious emotion of the worker with the work load, the tension and concentrated state and the change in the skin blood flow is considered to be related, because of the nature of the sympathetic nerve to constitute the autonomic nervous. It is known that AVA only exists in the skin of the hairless part such as limbs, lips, nose, and ears [5]. In this study, in order to realize a low-load measurement for a human, it is easy to observe the blood flow change by AVA, and the face that is exposed on a daily was measured.

2 EXPERIMENT

2.1 Measurement of blood flow signals

The response of the blood flow change is detected by taking pictures of the face with a general-purpose camera and analyzing the captured images when human rests and works. The camera is used a commercially available WEB camera (C922n Logicool) to capture images. A signal value is calculated by using each pixels based on the wavelength penetration difference method by using the intensity of the target corrected and the images of the biological tissue.

Human skin (hereafter simply referred to as "skin") is composed of subcutaneous fat, Dermis, blood capillaries, and the like, and each of them has unique optical properties. The modeling of the interior of the skin which is necessary for measuring the blood flow in the skin is shown in Fig.1. It is based on the viewpoint of measuring the blood flow of the skin interior with light. The skin has a three-layer structure consisting of the epidermis, dermis, and subcutaneous tissue.

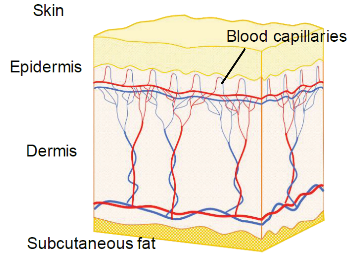

Fig.1 Cut Model of skin

Each of layers has own optical property. The degree of penetration of light into biological tissues ("penetrance," hereafter) varies according to the light's wavelength, and in the visible-light region of 380 to 780 nm, longer-wavelength light penetrates. The blue component of light (represented by "B" in the tables, and equations hereafter) (around 435.8 nm on the short-wavelength side in the visible light region) penetrates the skin surface, the green component of light ("G") (around 546.1 nm) reaches capillaries of the epidermis, the red component of light ("R") (around 700.0 nm) reaches the lower papilla containing the dermal capillaries, and infrared light (IR) (around 830.0 nm) reaches deeper. As shown in Fig. 2, the penetrance of light used for measurement becomes deeper in the ascending order of blue, green, and red and the penetrance of three types of light is expressed in terms of l being the depth into of the human skin.

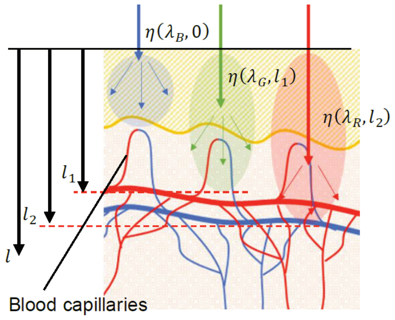

Fig.2 Penetrance of color lights

As for the three components (red, green, and blue) of the light irradiated onto the skin from a camera or ambient light, light reflected from the surface and light returning to the skin surface (after some of it has been scattered, absorbed, and reflected while penetrating the human skin) is detected by the light receiving surface of the camera (photo detector). Here, we only consider the three light components (red, green, blue) that can be detected by the camera. Accordingly, if the depth at which blue light penetrates the skin and returns to the skin surface to be measured is assumed as $l = 0$, the depth green light penetrates and returns is assumed as $l \le l_1$, and the depth red light penetrates and returns is assumed as $l \le l_2$, the photo detector detects the light returned to the camera (reflected light) that contains information according to three different depths. The detected signal includes information about the surface of the skin ($l = 0$), information about the region from surface to near the capillaries ($0 < l \le l_1$), and information about the region from the surface but also including the capillaries ($0 \le l \le l_2$). Since it is possible to measure with a camera, and the depth l of capillaries in the human skin in which blood flows is assumed as $l_1 < l < l_2$, green light and red light can be used to measure the blood flow. If common information (unnecessary components) can be removed from the two types of light information by calculation, it would be possible to visualize only information about skin blood flow.

Among the obtained two-dimensional blood flow signals, the average value of the signal values contained in the inside of each of the rectangular measurement regions defined corresponding to each part of the face is calculated for that region at that moment. If the size of the measurement area is a square of N pixels and the signal value at the local coordinates (i, j) in the measurement area is $S_{i,j}$, the representative value S of the measurement area is calculated.(eq.1)

$$S = \frac{1}{N^2} \sum_{i=1}^{N} \sum_{j=1}^{N} S_{ij} \qquad \text{(eq.1)}$$

2.2 Protocol of Task test

In this experiment a change of Unconscious Perceptual Information of research subjects is measured by using camera. We measure the blood flow changes when research subjects receive work load.

Table 1 shows the time table of this protocol.

Table 1 Time table

[sec]	60	60	60
Rest	Rest(1st)		-
Work Load	Rest(1st)	Task	Rest(2nd)

In the condition of "Rest", it takes the video for 120 seconds with eyes closed. In the condition of "work load", research subjects rest (Rest 1st) with closing the eyes for 60 seconds, then calculate mental arithmetic (Task without exercises) for 60 seconds. They need to continue to add 17, and to answer as much as possible. After the calculation, they close the eyes again, and rest (Rest 2nd) for 60 seconds (a total of 3 minutes).

In particular, measurement areas focused on the cheek and nose areas because effects of AVA related with autonomic nervous system. The signals S in nose and cheek areas are measured and the signals plotted on the horizontal (S in nose area) and vertical (S in cheek area) axes, respectively, and the correlation was confirmed. The two-dimensional blood flow signal was calculated from the value of each pixels.

3 RESULTS

Fig.3 shows that the blood flow signal is analyzed from the image of the face. A blood flow in the red area is more than one in the yellow area. The algorithm for calculating the blood flow signal is used for the wavelength difference detection method. The blood flow signals are calculated by extracting images captured every second from the video. In the analysis, we make a comparison between blood flow signals in the resting and in the mental arithmetic calculating as a workload.

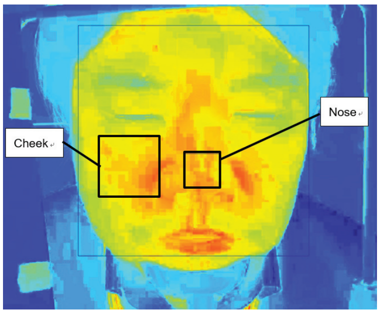

Fig.3 Distribution of Blood Flows Signal in the Face

Fig.4(a) and Fig.4(b) show the information based on the blood flow signals in the "Rest". Fig.4(a) shows blood flow signals in a nose and in a cheek, and Fig.4(b) shows the balance of blood flows in a nose and in a cheek. There was a variation in the blood flow signal in the nose and the cheek, and was not in a complete linear relation. The coefficient of determination was 0.87, which showed a high correlation at the "Rest" in 120 seconds.

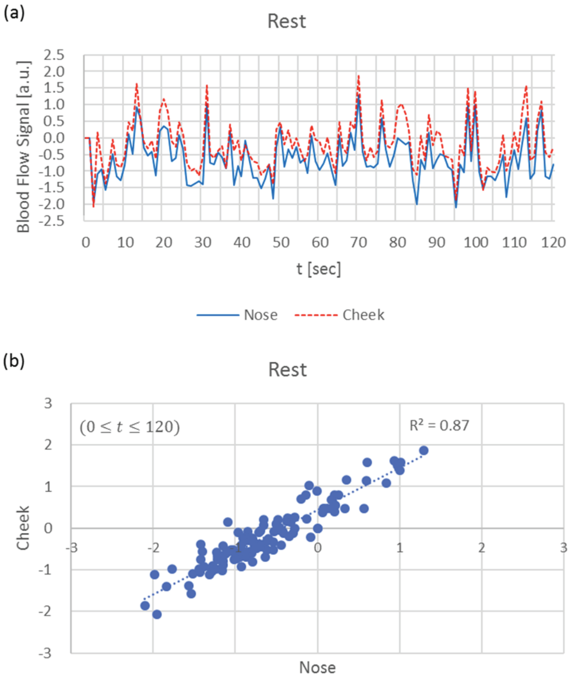

Fig.4 (a) Blood Flows Signals in the Rest, (b) Balance of Blood Flows Signal in the Rest

On the other hand, Fig.5(a), (b), (c), and (d) show the information based on the blood flow signals in the "Work Load". Fig.5(a) shows the blood flow signals in a nose and a cheek. The coefficient of determination was 0.65 in the experiment during 60 seconds to keep the rest (Rest 1st) . Fig.5(b), (c), and (d) show the balance of blood flows in a nose and a cheek. It was decreased to 0.55 during 60 seconds to calculate (Task). After the task, the 60 seconds rest (Rest 2nd) was given, and the coefficient of determination increased to 0.81. It was confirmed that the blood flow balance was effected by an action.

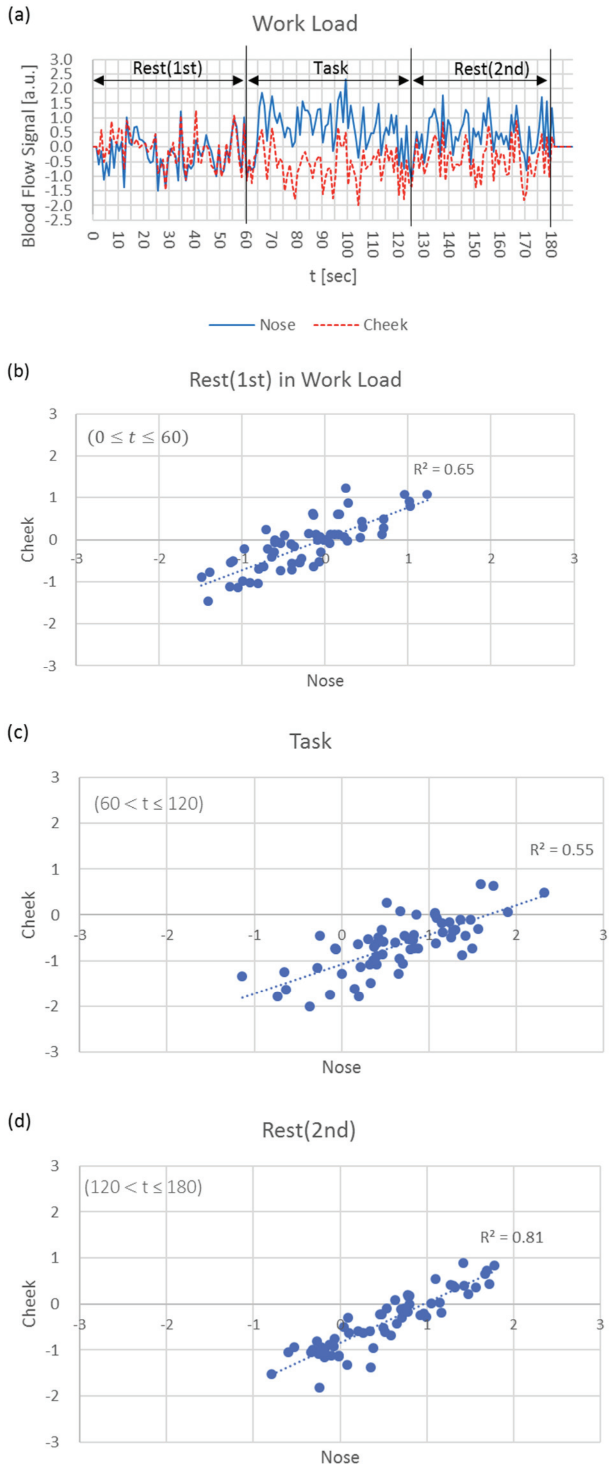

Fig.5(a) The blood flows signal in the Work Load, Fig.5(b) The balance of blood flows signal in the Rest 1st, Fig.5 (c) The balance of blood flows signal in the Task, Fig.5(d) The balance of blood flows signal in the Rest 2nd

4 DISCUSSION

The changes in facial blood flow can be measured from images with the wavelength penetration difference detection method by using a general purpose camera, and the blood flow signals in a nose and a cheek regions are measured. Table 2 shows the correlation coefficient between the blood flows in the nose and in the cheek. A correlation coefficient is a square root of a determination coefficient.

Fig.6 shows that correlation coefficients in the "Rest" are higher than in the "Task". It was confirmed that the correlation coefficient declined when human worked. This result suggests the possibility of being able to objectively estimate the work load without going through the process of asking questions to know the states of human and obtaining subjective answers.

Table 2 correlation coefficient

	Rest(1st)	Task	Rest(2nd)
Rest	0.94	-	-
Work Load	0.81	0.74	0.90

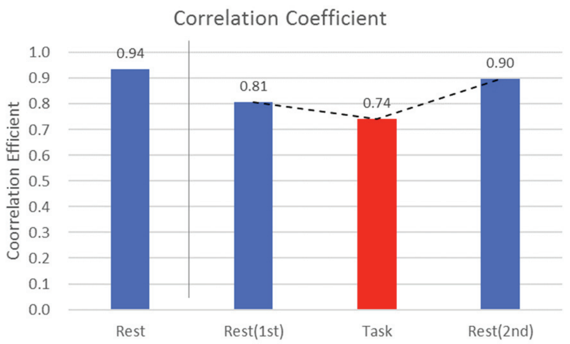

Fig.6 Decline of correlation coefficient in Task

5 CONCLUSIONS

We could analyze the properties of the facail blood flow from the camera image using a video-based method. We found the difference of the correlations of the blood flow signal in the nose area and cheek in resting or working. This result suggests the possibility of objectively estimating the states of the workload without having to ask questions in order to know the condition of human and to obtain a subjective response. Using a general-purpose camera, we confirmed the possibility of detecting changes in human being that received the worker load in a non-contact manner. We detected the signal differences in the resting state and the task was operated.

6 REFERENCES

[1] John M Karemaker., "An introduction into autonomic nervous function," IPEM Physiological Measurement, Vol. 38, No. 5 (2017).

[2] Lars Walløe., "Arterio-venous anastomoses in the human skin and their role in temperature control," Temperature (Austin). 2016 Jan-Mar, 3(1), 92–103 (2016).

[3] Kashima H, Hayashi N.,"Basic taste stimuli elicit unique responses in facial skin blood flow," PLoS ONE 6(12): E28236 (2011).

[4] Kashima H, Hamada Y, Hayashi N.,"Palatability of Tastes Is Associated With Facial Circulatory Responses," Chem. Senses, 39:243-248 (2014).

[5] Hirata K.,"Blood Flow through Arteriovenous Anastomoses (AVA) and Regulation of Heat Losses from the Extremities in Human," Jpn. J. Biometer. 53(1):3-12 (2016)