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FACIAL EXPRESSIONS DUE TO POSITIVE FEELINGS OBSERVED USING VISIBLE SPECTRUM AND NEAR INFRARED IMAGES

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Abstract. *Japan has an aging population and improving the quality of life of individuals is necessary to maintain social vitality. Therefore, the demand for life support systems for environment and health monitoring is increasing. A particularly important aspect of such systems is the ability to recognize happiness. Recognition of facial expressions is necessary to enable emotional communication with machines. However, it is difficult to recognize and distinguish between slightly varying facial expressions such as happiness by using information in the visible spectrum. In this study, we investigate the features of changes in facial expressions arising from the emotions of amusement and happiness. We take account of visible information acquired by a visible spectrum video camera and near infrared (NIR) information acquired by an NIR camera. Based on the experimental results obtained from four subjects, the study offers a few suggestions for recognizing and distinguishing between target emotions.*

Keywords: Detecting positive emotion, Near infrared, Quality of life, Human sensing

1. **Introduction.** Japan is a nation with a very high proportion of aging population, resulting in a growing need for social security payments. To reduce the burden of social security payments, there is a need to maintain and improve the health of the elderly. One possible solution for this issue is an overall improvement in the quality of life (QOL) for individuals. It has also been observed that a feeling of happiness or well-being has a positive effect on human health. Improving the QOL for individuals tends to increase social vitality. To realize this goal of improving and maintaining the QOL for individuals, there is a growing demand for life support systems that use information technology, such as QOL monitoring systems. The supporting system must recognize human feelings to judge whether the user is comfortable or not. A considerable amount of research has been conducted to recognize facial expressions from images of faces captured in the visible range, which has revealed the usefulness of recognition of emotions [1-5]. However, it is particularly difficult to recognize emotions such as happiness with only minor changes in expression. To solve this issue, multiple sensing is useful: visible information, face temperature with thermal vision [6-8] and near infrared information [9].

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In this study, we investigate the features of change in a facial expression arising from amusement and happiness. We take account of visible information acquired by a charge coupled device (CCD) image sensor camera and near infrared (NIR) information acquired by an NIR camera. We observed facial changes due to emotional expression from visible and NIR images. NIR is widely used in security or medical fields such as a vein authentication system [10] or an intravenous injection support system [11]. We tried to investigate information related to hemodynamic changes in venous blood using NIR images. We then analyzed the differences between facial expression features from the results of visible and NIR images. Furthermore, we investigated the usefulness of NIR information for detecting happiness emotion.

This paper consists of six sections. The background and purpose of this study are described in Section 1. In Section 2, we describe the definition of target emotion, and eliciting procedure of the target emotion in this study. In Section 3, we describe the detail of data used in this study: data acquisition environment and acquisition process, and extraction procedure of data sections. In Section 4, data analysis procedures are described: definition of region of interest, extraction of features for analysis. In Section 5, the analysis result is described, and we discuss the feature changes before and after emotion is evoked in visible and NIR images. The analysis aims to investigate a tendency of the feature changes between normal state and emotion evoked state. Section 6 discusses the conclusion of this study.

2. **Target Emotion.**

2.1. **Definition of target emotion.** In this study, two types of pleasing emotions were considered as targets: "amusement" and "happiness". The definition of "amusement" is provided in [12]. On the other hand, "happiness" may have various connotations, all of which evoke positive emotions. To evaluate the targeted emotion quantitatively, it needs to be evoked frequently. Hence, we limited "happiness" to two representative emotion units used in psychology based on [13]. We further subdivided happiness into two types of emotion: "heartwarming (a sweet feeling)" and "peaceful (a calm feeling)" in this study. These two types of emotions are positive feelings that can be evoked in a subject passively by showing suitable images.

2.2. **Stimuli for eliciting emotions.** To select movies that evoke heartwarming and peaceful responses, a survey was administered through questionnaires on 19 people. Each subject evaluated the intensity of the two target emotions for nineteen movies based on natural scenery, six kinds of pretty animals, and children. Two points were assigned to the movie if they felt a strong emotion: one point if they felt a weak emotion, and zero points if they felt no emotion. The results of the questionnaire are shown in Figure 1.

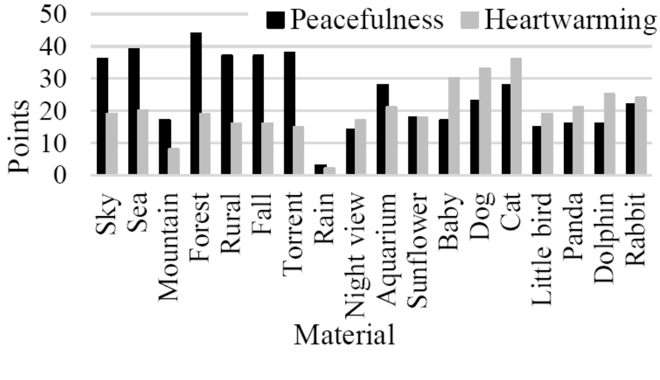


FIGURE 1. Results of emotion-eliciting questionnaire

Scenes from nature easily evoke peacefulness but are not as effective in evoking heartwarming emotions. On the other hand, pictures of animals and children effectively evoke heartwarming emotions.

According to those results, we selected five types of movies on topics like the "sky", "sea", "forest", "cats", and "dogs" to evoke a target emotion. Moreover, we used these movies to suit each subject's taste based on their answers to the questionnaire.

3. Data Used.

3.1. Data acquisition. Figure 2 shows the data acquisition environment and timeline. We recorded the facial expressions of thirteen subjects (subjects A-M) watching a few short movies [14-17] as the stimuli for eliciting emotions. The subjects' facial data were acquired by a CCD camera (Point Grey Research: Grasshopper) and an NIR camera (Ximea: XiQ). We prepared three short movies: one movie was a 5 min-long funny television program for eliciting amusement and the other two movies involved scenes from nature or pretty animals. After watching these movies, each subject intuitively evaluated the intensity of the evoked emotion using an Affect Grid [18]. Furthermore, in the experiment, whenever a feeling of amusement was evoked, the subjects evaluated the intensity of this feeling for every such section on a grade of 0-3. A detailed evaluation is not carried out for the feeling of happiness because the expression and disappearance of happiness-related emotions are difficult to judge. Data acquisition was performed for three days. Each day, the subject watched a different stimulus. The data used in this study were acquired with the approval of the ethical regulations regarding studies in humans at Akita University, Japan.

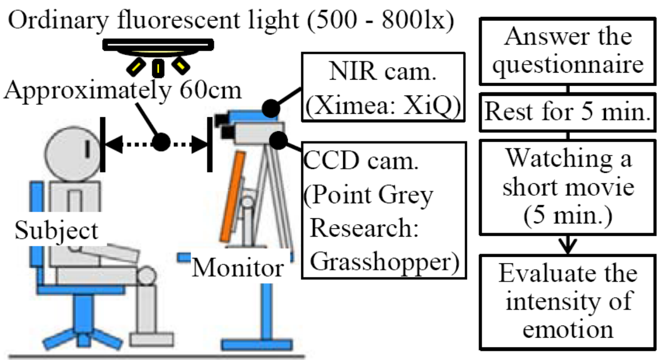


Figure 2. Data acquisition environment

3.2. Extraction of sections displaying target emotion. The videos were converted to 8-bit grayscale static images (60 frames/s; 320×240 pixels). Next, we extracted a 20-frame segment of the hardest laughter segment from each acquired video to evaluate the feelings of amusement. From the happiness data, we extracted two sections: "data before emotion evoked" and "data after emotion evoked" from the same video. Each extracted section was 20 frames long. The first section was extracted right at the start of watching the short movie, and the other section was extracted 2 min and 30 s later.

4. Data Analysis.

4.1. Definition of region of interest. We focused on the three facial regions: the right and left cheeks and the bridge of the nose based on [8] (see Figure 3). The regions of either cheek were defined by rectangles with solid white outlines along two dotted black lines. Of these two lines, the upper horizontal line runs along the lower border of the eyes, and the perpendicular lines run along the right and left ends of each eye. The rectangles of each

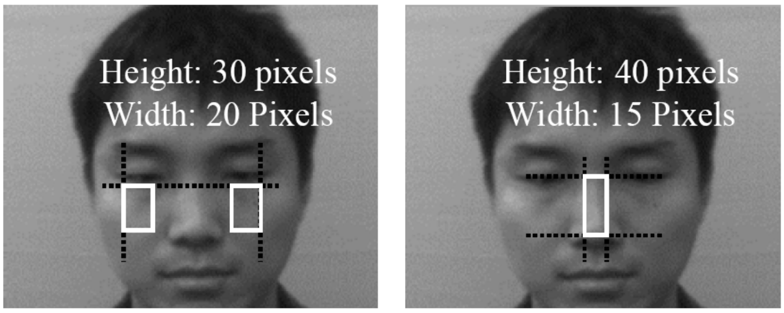


Figure 3. Definition of ROIs

cheek were set to 20 pixels wide and 30 pixels high on the basis of the intersection point of the upper horizontal line and the perpendicular line. The nasal region was defined by a rectangle enclosed by a horizontal line running along the lower border of the eyes and the apex of the nose, and perpendicular lines along the right and left ends of the bridge of the nose. The basic size of the nasal region was 15 pixels wide and 40 pixels high. Further, glasses and hair were excluded from each rectangle. The image data analysis was performed on four subjects for whom the region of interest (ROI) could be easily extracted.

4.2. **Data analysis procedure.** We assumed that a gradation distribution due to the capillary blood flow is clearly expressed in the gray-scale facial images acquired by NIR camera compared with that of visible spectrum images. Therefore, we focused on the histogram of the gradation value in the target area to calculate feature values for investigating the difference between ordinary state data and emotion evoked state. Figure 4 shows the outline of the data analysis procedure used in this study. To take account of the changes observed in the target regions when the feelings of amusement and happiness arose, the following procedures were performed.

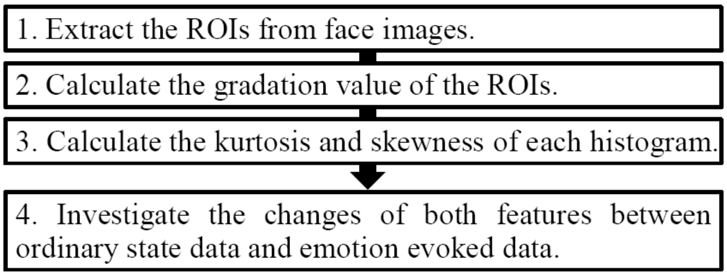


Figure 4. Data analysis procedure

First, the ROIs were extracted from each face image. We set the rectangle of ROI for the initial frame of the extracted section manually. Second, the gradation value of the target regions was calculated. Then, a histogram of this gradation value was created. Third, the kurtosis and skewness of each histogram were computed using Equations (1) and (2).

$$\text{Kurtosis} = \frac{n(n+1)}{(n-1)(n-2)(n-3)} \sum_{i=1}^{n} \left(\frac{x_i - \bar{x}}{s} \right)^4 - \frac{3(n-1)^2}{(n-2)(n-3)} \tag{1}$$

$$\text{Skewness} = \frac{n(n+1)}{(n-1)(n-2)} \sum_{i=1}^{n} \left(\frac{x_i - \bar{x}}{s} \right)^3 \tag{2}$$

where x_i represents the value of each data, n is the number of pieces of data, and s is the standard division. Finally, we investigated the changes in the kurtosis and skewness values between ordinary state data and emotion evoked data.

5. **Result and Discussion.** We focused on kurtosis and skewness of histogram of ROIs in each emotion state. The deviation of the distribution shape from normal distribution could be expressed by these two values. Therefore, we adopted the kurtosis and skewness as analysis features for investigating the transition of the gradation value of the ROIs.

5.1. **Transition of the subjects' feelings.** Figure 5 shows the evaluation results using an Affect Grid [18] for thirteen subjects. The Affect Grid is a single-item scale with two dimensions. The vertical dimension represents the degree of arousal, and the horizontal dimension represents the degree of pleasantness. The subjects intuitively marked their present feeling on the Affect Grid. In this study, subjects marked their feeling before and after they watched the emotion-eliciting movies. We calculated the average points of arousal (A-Score) and pleasantness level (P-Score) for every subject.

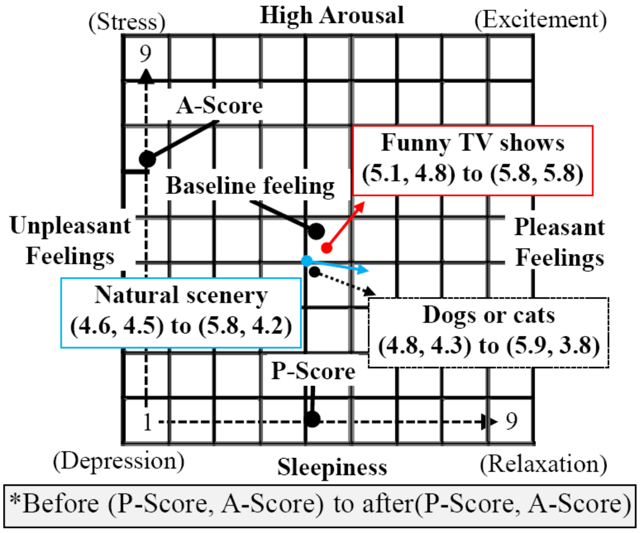


Figure 5. Evaluation result using Affect Grid

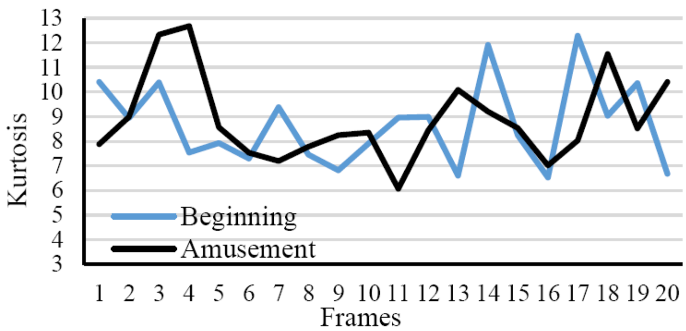
From the results, both scores increased when the subjects watched comedy programs on the television. This result suggests that the subjects' feelings have been altered to excitement. On the other hand, subjects who had watched natural scenery show an increase in the P-score and a decrease in the A-score. This result suggests that the subjects' feelings have altered to relaxation. Similarly, subjects who had watched movies involving pretty animals exhibited an increase in the P-score and a decrease in the A-score. These results suggest that the amusement feeling associated with laughter pertains to the emotion of excitement, and the peacefulness and the heartwarming feelings pertain to the emotion of relaxation.

5.2. **Feature analysis result of NIR data.** Table 1 shows the rate of change in the features for the four subjects as reflected by NIR data. The rates were calculated from the average value of each section (20-frames) for four subjects. Kurtosis and skewness values of both cheeks decreased when a feeling of amusement was evoked in the subjects. The mean values of the rate of changes for the four subjects are -51.5% (kurtosis) and -30.3% (skewness) in the left cheek region and -45.1% (kurtosis) and -26.9% (skewness) in the right cheek region. On the other hand, kurtosis values for both the cheeks were slightly increased when heartwarming or peaceful feelings were evoked in the subjects. Next, we focused on the nasal region and observed that kurtosis and skewness increased with both the emotions. Significant changes were observed when heartwarming feeling was evoked.

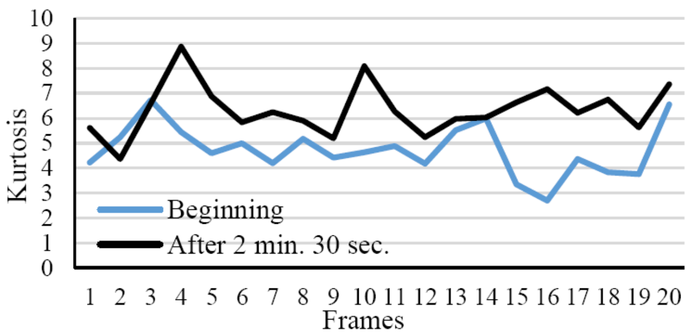
Figure 6 shows the feature transition result of the nasal region based on the NIR image data for each emotion. Kurtosis becomes larger when subjects experienced a heartwarming emotion and peaceful feeling in the overall region (see Figures 6(b) and 6(c)). The change

Table 1. Degree of feature changes before and after emotion is evoked in NIR images

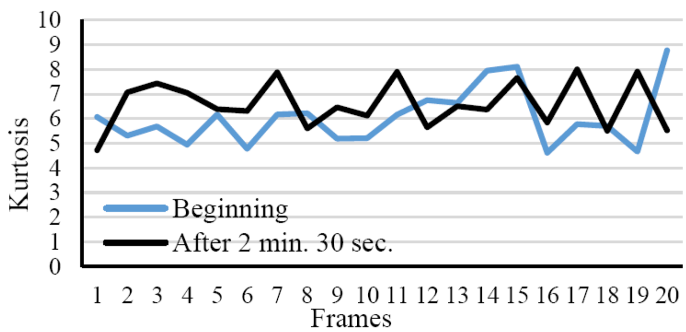
Evoked feeling	ROI	The degree of feature change	
		Kurtosis	Skewness
Amusement	Left cheek	−51.5%	−30.3%
	Right cheek	−45.1%	−26.9%
	Nose	2.1%	2.4%
Heart-warming	Left cheek	5.2%	0.4%
	Right cheek	6.4%	3.4%
	Nose	**33.9%**	**13.1%**
Peacefulness	Left cheek	3.7%	3.1%
	Right cheek	1.8%	1.9%
	Nose	9.1%	3.8%



(a) Amusement



(b) Heartwarming feeling



(c) Peacefulness

Figure 6. Kurtosis transition of nasal region in NIR data (mean value for 4 subjects)

of kurtosis showed an increasing tendency of the maximum frequency and the nearby values when a heartwarming and peaceful emotion raised. It is thought that a change of blood flow dynamics state in ROIs might be observed by the kurtosis. From these results, it is seen that the kurtosis and skewness values in the ROIs can be useful parameters for detecting an arising heartwarming and peaceful emotion. On the other hand, in the case of the feeling of amusement, the feature transition did not clearly manifest itself, as shown in Figure 6(a). Therefore, we have to conduct more research about the feature change in the state of amusement.

5.3. **Feature analysis result of visible data.** Table 2 shows the rate of change of the features for four subjects in visible data obtained from CCD video camera. The rates were calculated in the same way as NIR data. Based on these results, no significant change was observed in the features when heartwarming and peaceful feelings were evoked. Moreover, the magnitude of change in kurtosis and skewness of visible data has the tendency to be smaller than that of NIR data. The fluctuation width of kurtosis and skewness were larger than that of other emotions, similar to the NIR data observed in the cheek region.

Table 2. Degree of feature changes before and after emotion is evoked in visible images

Evoked feeling	ROI	The degree of feature change	
		Kurtosis	Skewness
Amusement	Left cheek	−40.4%	−22.7%
	Right cheek	−9.1%	−4.3%
	Nose	−1.2%	2.0%
Heart-warming	Left cheek	−1.6%	−0.6%
	Right cheek	−6.5%	−2.3%
	Nose	5.4%	5.1%
Peacefulness	Left cheek	−0.6%	1.4%
	Right cheek	−2.3%	0.3%
	Nose	−5.0%	−1.5%

These results suggest that the NIR sensing is more efficient than visible sensing in detecting the occurrence of target emotion, especially for detecting “heartwarming” and “peaceful” emotions.

6. **Conclusion.** We investigate the changes in facial features when emotions of amusement and happiness arise. We observed facial changes due to emotional expression using visible and NIR images and analyzed image data to obtain information specific to hemodynamic changes in venous blood. Our experiments provided the following conclusions.

- The kurtosis and skewness of the ROIs can be useful parameters for detecting heartwarming and peaceful emotions.
- The NIR sensing is more efficient than visible sensing to detect the occurrence of “heartwarming” and “peaceful” emotions.

For future work, we plan to increase the number of subjects, and we plan to further analyze the relationship between the target emotion and the acquired data. Additionally, we will investigate the relationship between the NIR data and blood flow using an observation apparatus for measuring the capillary blood flow in the fingertip.

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