



# Analysis of Melanin Pigment Changes in Long Terms for Face of Various Ages: A Case Study on the UV Care Frequency

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**Abstract.** In this study, we have analyzed individual differences in how the melanin component changes with time in 2003, 2010 and 2015. The frequency of use of protection against ultraviolet rays (UV) is considered to be a factor that causes individual differences in aging. Melanin is produced in human skin by exposure to UV, which promotes aging effects such as darkening and unevenness of skin color. In our previous work, we applied principal component analysis (PCA) to the distribution of melanin pigment and obtained feature values which quantitatively describe it. Furthermore, we found that the melanin component especially around the cheeks tends to increase with age. Comparing the melanin feature values for each frequency of use of UV protection, we found that the daily UV care even in winter can reduce the melanin component of face. In our previous work, we analyzed the database of facial images taken in 2003 and 2015. In this study, adding new facial data for 2010, we constructed a database of facial images captured in 2003, 2010, and 2015. It includes photographs of 60 subjects each in 3 years. The database also includes subjects' frequency of using UV protection. Applying the same analysis as our previous study, we obtained principal component (PC) scores, which describe the changes in individuals' faces in 2003, 2010 and 2015. From trends in these data, we found that the daily care for 12 years can suppress increasing the facial melanin component.

**Keywords:** Principal component analysis · Pigment distribution · Human face Ultraviolet rays · UV protection · Melanin

## 1 Introduction

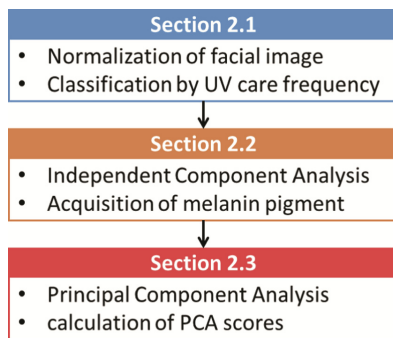
There are many researches on the simulation of facial appearance in recent years. Processes for obtaining facial features which are simplified for practical use have been

studied. For example, Principal Component Analysis (PCA) makes it easier to obtain facial feature values. Lantis *et al.* provided a framework for the simulation of aging effects on facial images. By applying PCA to facial landmarks, they simulated facial structure at any age based on classification by age [1]. Suo *et al.* also predicted the changing appearance of faces over long periods from changes to parts of the face over short periods based on the result of applying PCA to a facial image database divided by parts or ages [2]. Also, Toyota *et al.* simulated how change looks of facial image from 20 s to 80 s by using Multiple Regression Analysis and PCA [3]. In this method, however, individual differences of aging are not considered. So, in our other previous work, we analyzed the database of facial images captured in 2003 and 2015 to see this variation, but this only in 2 years [3].

In this study, new facial data for in 2010 was added. Also, we obtained individual differences in variation of the melanin component, which is greatly related to aging of human face. How frequently use protection against ultraviolet light (UV) was noted as a factor causing individual differences in aging. We analyzed changes in melanin pigment of the same person over 12 years, and found a relationship between the use of UV protection and melanin pigment.

## 2 Facial Image Database and Methods of Analysis

This section describes the construction of a facial image database, and the methods to obtain melanin pigment distributions for the whole face and their feature values. The outline of the procedure in this section is shown in Fig. 1.

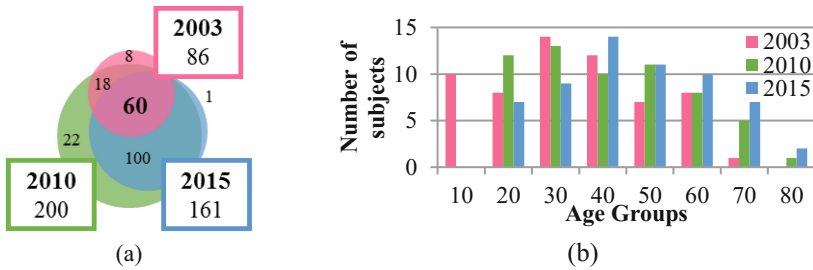


**Fig. 1.** The outline of the procedure in this section.

### 2.1 Construction of the Facial Image Database

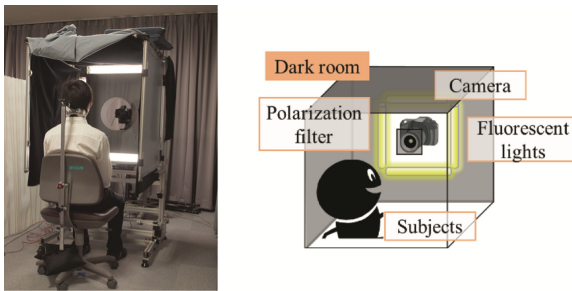
We constructed a database containing facial images, real ages, and the frequencies of UV protection use. We captured the faces of Japanese women whose ages were between 10 and 80 years, in the winters of 2003, 2010, and 2015. The number of subjects was 86 in 2003, 200 in 2010, and 161 in 2015, and the total number of facial images was

447 (see Fig. 2(a)). In the following analysis, we used only 180 facial images total of 60 women common to all the years shown in Fig. 2(b).



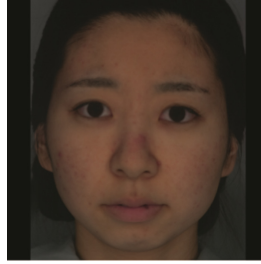
**Fig. 2.** Summary of data in the database: (a) breakdown of the numbers of subjects in 2003, 2010, and 2015, (b) age distribution of 60 subjects in common

The facial images were obtained by the experimental setup shown in Fig. 3. This imaging system was surrounded by blackout curtains to remove the effects of ambient light. Fluorescent lamps surrounding the camera were used as light sources. The camera was a Nikon D1 or Nikon D2H; the former was used in 2003 and the latter was in 2010 and 2015. In order to prevent movement of the face, we used a support for the neck and head, which was fixed to the backrest of the chair. We obtained facial images without specular reflectance by arranging mutually perpendicularly polarization filters in front of the camera and the light sources. There were differences in color tone of images taken in 12 years, because of the use of different cameras. In order to correct, we performed color matching by using Multiple Regression Analysis.

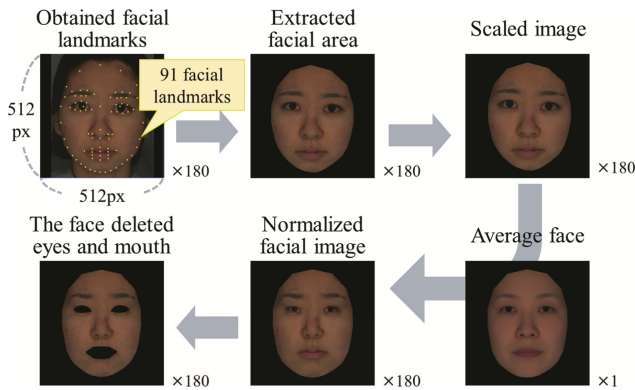


**Fig. 3.** Overview of the imaging system used.

Figure 4 shows an example of the captured facial images. These images needed to be normalized in order to remove the influence of variation in individual facial shapes when subsequently applying PCA. For this purpose, we used FUTON (Fool-proof UTilities for facial image manipulatiON system), which is a facial image synthesis system developed by Mukaida *et al.* [4]. Images of only the skin region are acquired by following steps shown in Fig. 5.



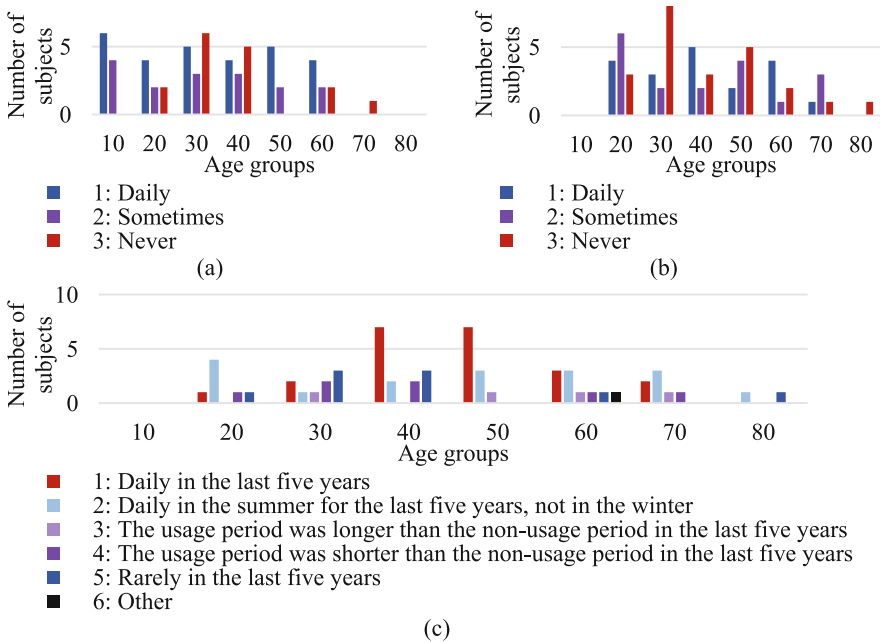
**Fig. 4.** Sample image.



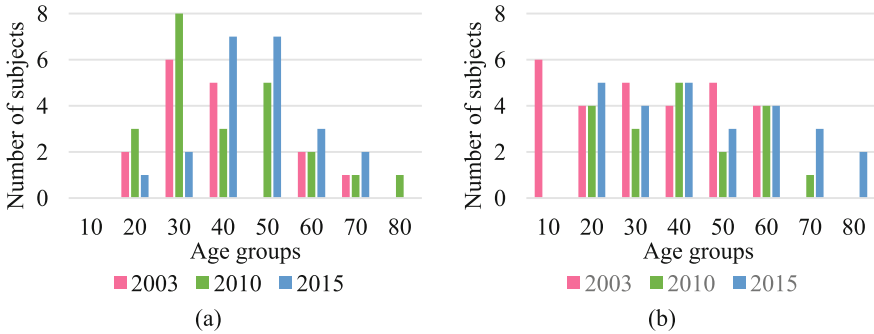
**Fig. 5.** Overview of normalization process for facial images by FUTON [4].

We classified facial images in the database according to the frequency of UV protection use by each subject. Frequencies were determined using a three-grade evaluation (1: Never, 2: Sometimes, 3: Daily) in the winters of 2003 and 2010, and a six-grade evaluation (1: Daily in the last five years, 2: Daily in the summer for the last five years, not in the winter, 3: The usage period was longer than the non-usage period in the last five years, 4: The usage period was shorter than the non-usage period in the last five years, 5: Rarely in the last five years, 6: Other) in the winter of 2015. Figure 6 shows the age distributions of frequencies of UV protection use.

Each subjects' frequency can be separated into two groups. Figure 7 shows the age distributions of these two groups. As shown in Fig. 7(a), one group is using UV protection daily throughout the years, consisting of 9 women who answered '3: Daily' both in 2003 and 2010, and in 2015 '1: Daily in the last five years. As shown in Fig. 7(b), the other group is NOT using UV protection in winter, consisting of 11 women who answered '1: Never' both in 2003 and 2010, and '2: Daily in the summer for the last five years, not in the winter' or '5: Rarely in the last five years' in 2015.



**Fig. 6.** Age distributions of the frequency of UV protection use: (a) in 2003, (b) in 2010, (c) in 2015.



**Fig. 7.** Age distributions by the frequency of using UV protection: (a) the group of daily using UV protection, (b) the group of NOT using UV protection.

## 2.2 Extraction of the Melanin Component

We obtained the skin pigment distributions by Independent Component Analysis [5]. An overview of the process is shown in Fig. 8. Melanin and hemoglobin pigment density vectors could be estimated by applying Independent Component Analysis (ICA) to the skin color of an arbitrary facial image in the database. Skin color pixel values were plotted in logarithmic space of RGB color space. For each skin color, these vectors were

projected onto the skin color plane in parallel with the shading vector. Melanin and hemoglobin pigment densities were obtained by projection onto each pigment density vector.

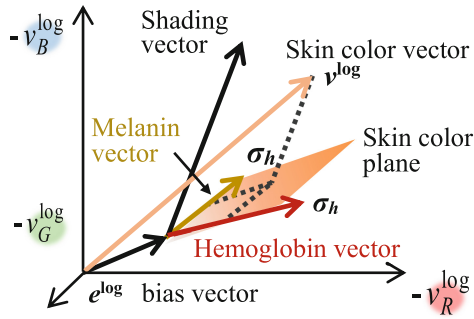


Fig. 8. Overview of ICA.

In this study, we used only the melanin component for analysis because melanin pigment has a high correlation with UV exposure. Figure 9 shows the example of extracted the melanin component by ICA. Compared with cheek image and melanin images, it can be seen that melanin representing brownish of the skin was separated.

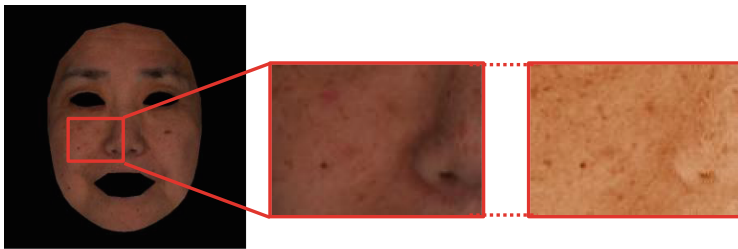


Fig. 9. Results the extracted melanin pigment components: the cheek area, of melanin pigment component.

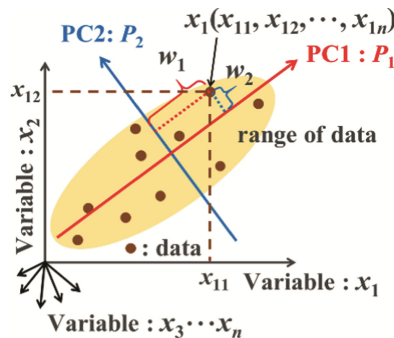
### 2.3 Analysis of the Melanin Component by PCA

We obtained feature values for whole facial pigment by applying PCA to the melanin components of the 180 facial images extracted in Sect. 2.2. PCA is a statistical method used to discern trends and features of data by multivariate analysis. It calculates the linear sum of each variable for each point in a data group, and defines a new index as the 1st principal component (PC1). The 2nd principal component (PC2) is defined in such a way that it is perpendicular to the PC1, and other principal components (PCs) are defined similarly. The  $n$ -dimensional  $i$ -th vector in a dataset can be represented as an approximated vector as follows:

$$\hat{x}_i(x_{i1}, x_{i2}, \dots, x_{in}) = \sum_{m=1}^M w_{im} p_m \tag{1}$$

where  $\hat{x}_i$  is each facial image,  $x_m$  is pixel value,  $M$  is the total number of PCs,  $w_m$  is the weight value for the  $m$ -th PC, called the PC score, and  $p_m$  is the  $m$ -th PC vector.

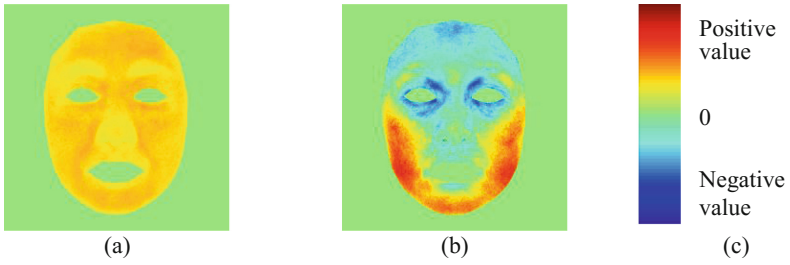
Figure 10 shows an overview of the PCA of melanin components of the facial images. PCA was applied to all pixels of the whole images. Since the number of pixels in the melanin images was  $512 \times 512$ , then each melanin image could be described by one data vector in  $512 \times 512$ -dimensional space (that is, we regarded one pixel as one variable). In this study, there were 180 data vectors shown in Eq. (1). We applied PCA to these data vectors to find the PC1 vector, such that the variance of the data vectors projected onto the PC vector is maximized. The PC2 vector is then determined as the perpendicular vector which gives the maximum variance when data vectors excluding the PC1 are projected onto it. The vector describing a melanin image can be approximated by the weighted linear combination of the first 2 PC vectors, if the contribution ratio of the 2 PC vectors to the melanin image vectors is high enough. Therefore, the extracted PC vectors and their weighting scores can be used to effectively analyze the very high dimensional data using a small number of variables.



**Fig. 10.** Overview of the PCA of image ( $n =$  number of pixels in the image).

Since there were 180 data vectors for subject’s melanin components in this study, we could obtain 179 PCs of their melanin pigmentation distributions. The first two of these are shown in Fig. 11(a), (b) These color is represented by jet color map shown in Fig. 11(c) [6]. When the PC vector is positive, it is colored positive direction in Fig. 11(c). Therefore, when the PC score is positive, melanin in red region are increased, and when the PC score is negative, melanin in blue region are increased.

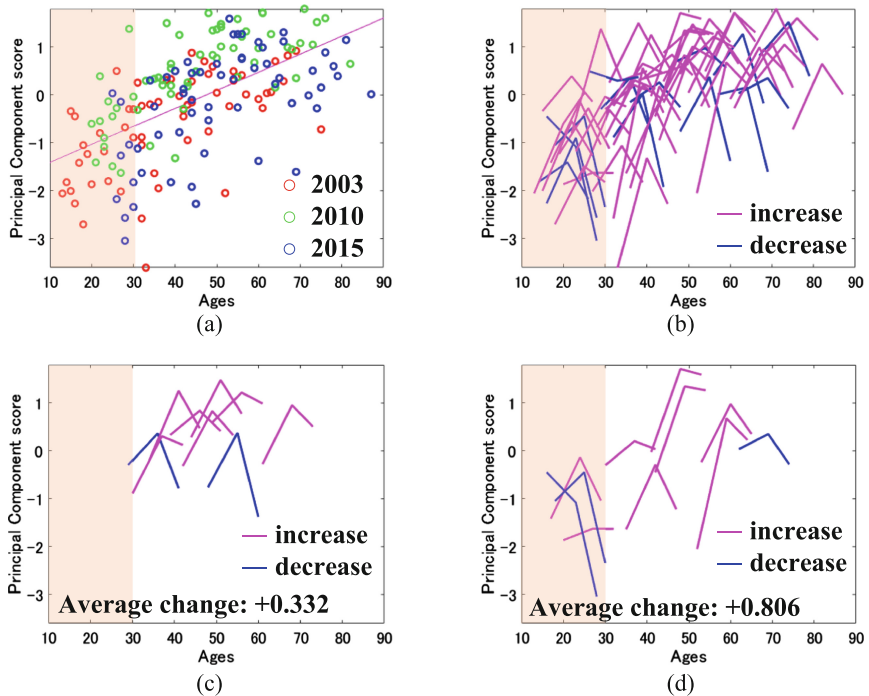
The PC1 represents melanin feature value in whole face and forehead, cheeks, and around mouth (contribution rate = 0.537). As the PC2, that is in such as cheeks, forehead and around eyes could be obtained (contribution rate = 0.040). Thus, we could obtain distinct feature values for the melanin component of the facial images.



**Fig. 11.** Results of PCA of the melanin pigment density: (a) the PC1, (b) the PC2, (c) jet color bar (Color figure online)

### 3 Results Showing Individual Difference in PC Scores

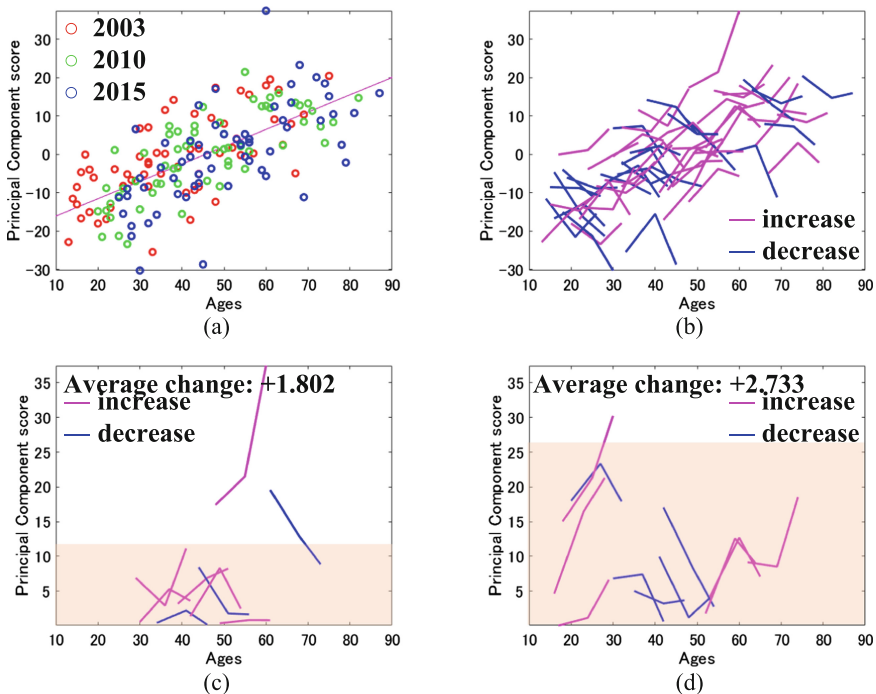
We obtained changes in the PC1 and PC2 scores over 12 years for each subject. PC1 scores are show in Fig. 12, and PC2 are in Fig. 13. These show the relationship between the PC1 or PC2 scores and age for the whole of study group and each individual. In Figs. 12(a) and 13(a), the marks represent the PC scores of individuals, and red marks



**Fig. 12.** Relationship between the 1st principal component scores and age by UV care: (a) whole of the study group, (b) individual changes, (c) the group of daily using UV protection, (d) the group of NOT using UV protection. (Color figure online)



show those of 2003, respectively green is 2010, blue is 2015. On the other hand, the magenta line represents a linear regression in which individual differences were not taken into account. The lines in Figs. 12(b) and 13(b) are connected between the data points in 2003, 2010, and 2015 for each individual. A red line means that the PC score is increasing, and a blue line means decreasing for 12 years. These graphs are separated into Fig. 12(c) and (d) or Fig. 13(c) and (d) based on frequency of UV protection. Figures 12(c) and 13(c) is the group “using daily UV protection”, and Figs. 12(d) and 13(d) is “NOT using daily UV protection”. Note that Fig. 12(c), (d) represented PC2 scores by absolute value. As shown in Fig. 10(b), since the PC2 appears in both positive and negative direction, the smaller the absolute value of the PC2 scores, the less the change in face. So it is better for the PC2 scores to be evaluated by the absolute value.



**Fig. 13.** Relationship between the 2nd principal component scores and age by UV care: (a) whole of the study group, (b) individual changes, (c) the group of daily using UV protection (abs), (d) the group of NOT using UV protection (abs) (Color figure online)

In PC1, the average change of “Daily using” is **+0.332**, and “NOT using” is **+0.806**. Therefore, the latter has greater changes in the whole face. On the other hand, in PC2, the average change of “Daily using” is **+1.802**, and “NOT using” is **+2.733**. Therefore, the latter has greater changes in the face of cheeks and forehead.

## 4 Discussion

Firstly, we discuss the first principal component. According to the regression line in Fig. 12(a), it can be seen that the PC1 scores also tends to increase as age increases. As shown in Fig. 12(b), PC scores of some women are increasing and others are decreasing. Compared with frequency of UV protection shown in Fig. 12(c), (d), there's similar results. In "NOT using" group shown in Fig. 12(d), we focus on the fact that there are two young subjects whose PC score is greatly decreasing. In this study, young people are defined as 10 s and 20 s. Also show in Fig. 12(b), young women tends to decrease PC scores. It means that these young subjects' melanin pigment in the whole face has decreased from 2003 to 2015. This may be due to factors such as lifestyle changes in young people other than the frequency of UV protection. For example, decrease of outdoor activities or much more active turnover of skin than higher ages may tend to decrease melanin pigment. Comparing the average change except 4 young women in Fig. 12(d), "Daily using" is **+0.332**, and "NOT using" is **+0.806**. Therefore, through analysis of PC1, we conclude that people with daily UV care except for young can suppress increasing melanin pigment in the whole face.

Secondly, we discuss the second principal component. As shown in Fig. 13(a), it can be seen that the PC2 score also tends to increase as age increases. Figure 13(c), (d) represented PC2 score by absolute value. Figure 13(c), (d) show the PC2 score represented by absolute values. Comparing the average change, "Daily using" is **+1.802**, and "NOT using" is **+2.733**. Therefore, through analysis of PC2, we found that people with daily UV care can suppress to change melanin pigment in face of cheeks and forehead.

## 5 Conclusion

In this study, we applied PCA to the melanin component of facial images and discovered individual differences in aging associated with the frequency of UV protection use. By considering individual changes in principal component scores in 2003, 2010, 2015, three years, and analyzing both positive and negative PC vector, we found a new relationship between the melanin component and age, which had not been recognized in previous studies.

In future work, we will attempt to predict the effect of UV protection by simulating facial appearance at arbitrary ages based on the relationship between the melanin component and UV protection. Also, we will analyze not only melanin in the whole face but also changes in high frequency components such as skin spots and wrinkles generated by UV.

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