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Luminance Distribution Effects on the Visual Quality of Human Skin

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ABSTRACT
To investigate how humans visually perceive the quality of their skin, we took photographs of the faces of 117 Japanese women. Subsequently, we cropped a square patch around the right cheek of every woman and presented to subjects that had to rate their perceived visual quality. In Experiment 1, we found that the perceived age was highly correlated with the number of wrinkles, the glossiness perception and the quantity of colored spots, whereas the visibility of pores and the color of the skin had low correlation. Moreover, the age perception also was significantly high correlated with image and sub-band statistics of the luminance channel. In Experiment 2, we built artificial images by using a histogram matching technique that modifies the luminance distribution but keeps the color and pattern information intact, and found that the modification of the luminance statistics on the skin texture resulted in a correlated modification in the perceived age and skin quality assessments.

Keywords
Luminance Distribution, Perceived Age, Statistics, Image Analysis, Skin, Visual Quality

1. INTRODUCTION
Cosmetic products are designed to reproduce the appearance of healthier and younger skin. Their efficacy assessment in modifying the appearance of the skin is a difficult process because it involves a complex quality discrimination made by the human brain using our visual perceptual system. Both shape and color information proved to be important cues when assessing the visual quality of human faces [1]. Herein, we focus on visual cues that can modify our skin quality perception besides color and global surface topography. Recently, a statistical approach to texture perception was adopted by Motoyoshi et al [2] who concluded that the perceived glossiness of a hand-made surface changes drastically only by modifying the skewness of the luminance histogram. This insight has been used by Wada et al [3] who showed that modifying the luminance statistics resulted in a correlated modification of the perceived freshness of cabbage leaves, suggesting that such approach can also explain other visual quality perception besides glossiness. The aim of this research is to investigate the effects of the luminance distribution statistics on the visual perceived quality of human skin. Our experimental settings permitted to evaluate stimuli with only variations in their luminance distribution without any change in the chromatic information.

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2. EXPERIMENT 1
2.1 Methods
2.1.1 Stimuli and Apparatus
We took photographs of the face of 117 Japanese women ranging in age from 13 to 80 years old (Mean: 40.1 years old; S.D: 17.4 years old) in a controlled environment with a professional digital SLR camera. The illumination was achieved with fluorescent lights with a color temperature of 5200K. Subsequently, we cropped skin patches and presented them as visual stimuli on a LCD monitor (Figure 3). The luminance and chromatic values of the monitor were calibrated manually using a photometric apparatus.

2.1.2 Participants
Ten Japanese observers participated in the experiments. All had normal or corrected to normal visual acuity.

2.1.3 Procedure
Subjects were asked to rate the perceived age of the stimuli by using a visual analogue scale. The stimuli were presented in random order and there was no restriction on response time. To test other visual qualities, we selected only 20 skin patches. Then, we presented them to subjects that used 5 rating scales: the number of wrinkles, the glossiness perception, the quantity of colored spots, the visibility of pores and finally the color of the skin. All scales were evaluated at 4 levels.

2.2 Results
Our results revealed a high correlation between perceived age and real age (Figure 1). Also, luminance spatial frequency, mean luminance and luminance skewness are significantly highly correlated with the perceived age of the skin (Table 1). Finally, the perception of the number of wrinkles, glossiness and the quantity of colored spots are highly correlated with the skin perceived age (Table 2).

Table 1. Perceived age and luminance statistics correlation

	Band-pass Filter 1-1.6(cycles/cm)	Mean Luminance	Luminance Skewness
R	0.81	0.61	0.50
p	<0.01	<0.01	<0.01

Table 2. Perceived age and other visual qualities correlation

	Wrinkles	Gloss	Spots	Pores	Color
R	0.91	0.91	0.89	0.41	0.00
p	<0.01	<0.01	<0.01	0.07	0.97

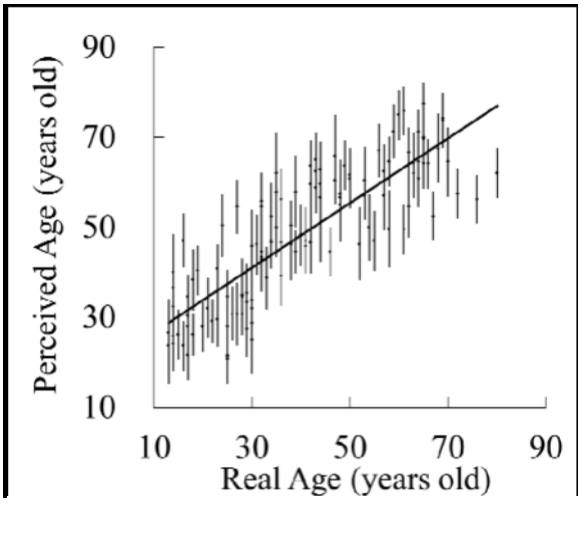

Figure 1. Real age versus average perceived age.

3. EXPERIMENT 2

3.1 Methods

3.1.1 Procedure and Apparatus

Same procedure and apparatus as in Experiment 1

3.1.2 Participants

Four subjects that also participated in Experiment 1

3.1.3 Stimuli

As visual stimuli, we used 40 artificially built skin patches based on 20 randomly selected original images and created using a luminance matching technique based on [4]. The artificially built stimuli were created only by modifying the luminance distribution of the images and keeping the chromatic information intact (Figure 4). Two groups of artificial stimuli were created: 20 skin patches with the luminance statistics of a younger patch (Matching to Young) and 20 skin patches with the luminance statistics of an older patch (Matching to Old).

3.2 Results

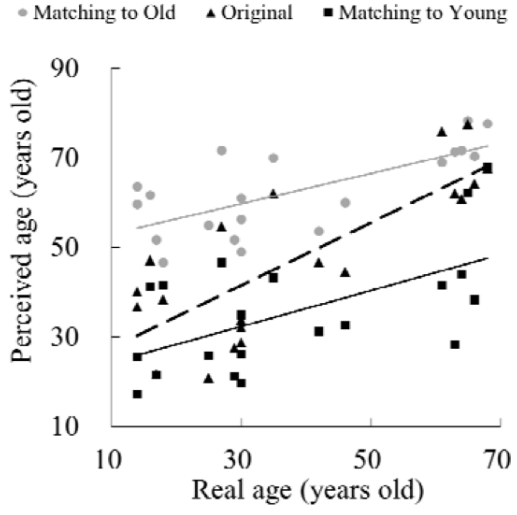

Figure 2. Real age versus average perceived age of the original and artificial stimuli.

Modification of the luminance statistics independently from colour information resulted in correlated modification of the perceived age (Figure 2). In Figure 2, gray and black lines represent linear regressions for the skin age perception results of the "Matching to Old" group and the "Matching to Young" group, respectively. The broken line is a linear regression for the original images used as base for the creation of the artificial images. Also, this artificial luminance modification affected other visual qualities except colour perception.

4. ANALYSIS AND DISCUSSION

Significant high correlation between the perceived and real age of the stimuli proves that our skin patches contain enough information for an age discrimination task. Stepwise multiple linear regressions were performed to model the perceived age using both, other visual quality perceptions (Equation 1) and luminance properties (Equation 2). Moreover, both linear regressions were highly correlated with the perceived age results (Figure 5).

Equation 1. Age estimation using other visual quality ratings

$$\begin{bmatrix} Perceived \\ Age \end{bmatrix} = 17.8 + 8.2 \begin{bmatrix} Wrinkles \\ Rate \end{bmatrix} + 8.8 \begin{bmatrix} Gloss \\ Rate \end{bmatrix} + 4.9 \begin{bmatrix} Spots \\ Rate \end{bmatrix}$$

Equation 2. Age estimation using luminance properties

$$\begin{bmatrix} Perceived \\ Age \end{bmatrix} = 21.8 + 2 \cdot 10^{7} \begin{bmatrix} SF \\ 1-1.6 \end{bmatrix} + 17.8 \begin{bmatrix} Skew \\ L \end{bmatrix}$$

In Equation 2, SF means luminance spatial frequency in cycles per cm and Skew L represents the luminance skewness.

5. CONCLUSIONS

We investigated the effect of the luminance distribution statistics on the perceived age of the skin by building artificial images with modified luminance distribution but intact color information. For this reason, we introduced the use of a simple image processing algorithm to independently control the luminance distribution which proved to modify the perceived age of the skin. Vision- based approaches can contribute to understand the role of human vision perception when confronted to age estimation. Here, we capitalized on this novel approach and found that luminance distribution plays an important role in age assessment. Our research results are steps towards a further understanding of how visual cues are interpreted by the human brain and how to model quality perception mechanisms such as the perceived age of the skin and other visual impressions.

6. REFERENCES

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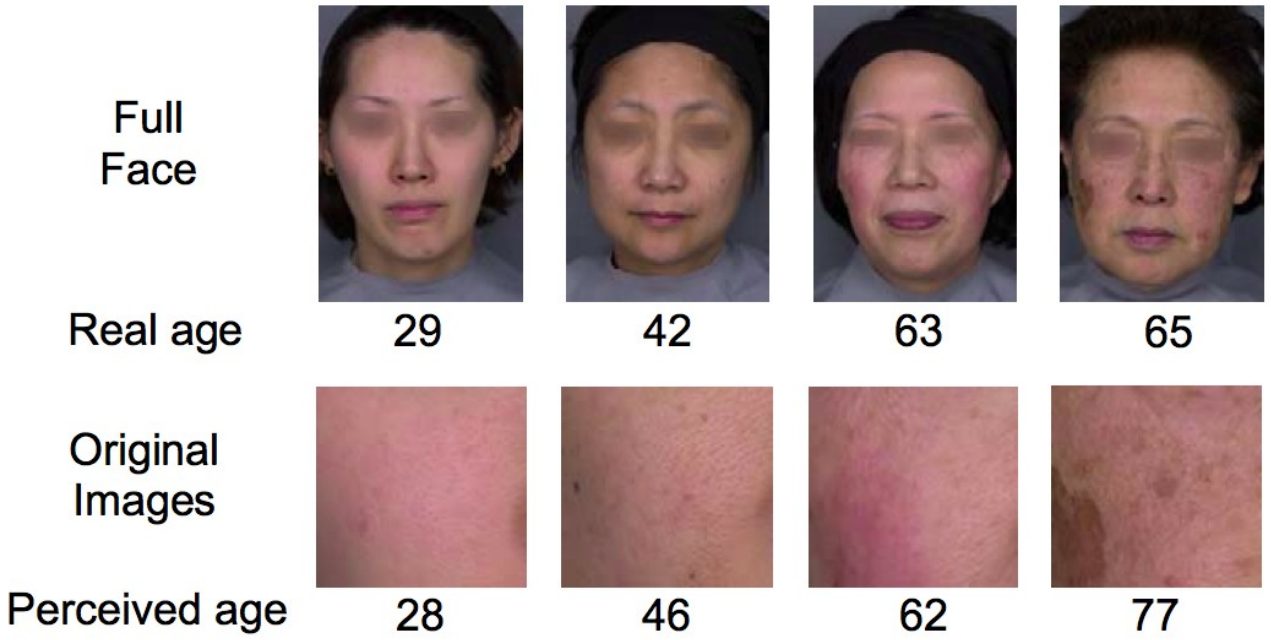

Figure 3. Example of the full face photographs with respective chronological age. Original skin patches used as stimuli with respective average perceived age (decimals removed).

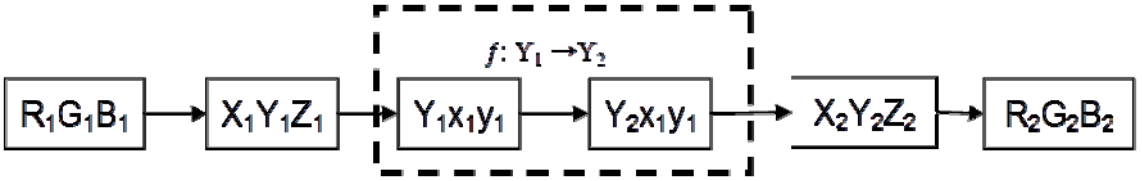

Figure 4. Flow diagram of the color conversion processing. The dotted-rectangle represents the luminance histogram matching process characterized by the conservation of x1 and y1 (chromatic information) and the modification f of Y (luminance) with respect to the matching technique.

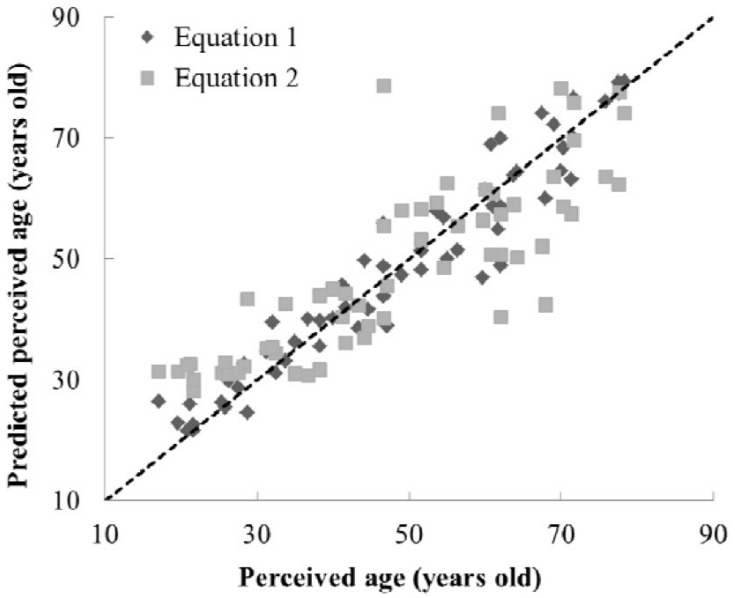

Figure 5. Perceived age against the prediction of age using Equation 1 and 2. Straight dotted line represents the ideal estimation.