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Skin Color Perception in Portrait Image and AR-based Humanoid Emoji

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Abstract

Animated emoji in augmented reality (AR) enables users to create a humanoid version of themselves that mimics their facial expressions dynamically. In this study, we aim to explore how people perceive facial skin color in digital portrait in comparison with humanoid emoji in AR. We tried to identify the skin color representative regions and to estimate the color difference between the two contexts. We conducted a user study comprised of three tasks with 20 graduate students majoring in design and employed 24 portrait images in four skin tone categories. Through the user study, we first figured out that forehead and cheek regions, and particularly the linking band between eye and lip, were often considered as the representative region of facial skin color. Second, we observed skin colors become lighter in general, except dark tone. Furthermore,concerning the vidvidness, all four skin tone types became paler in humanoid emoji. Diverse ethnicities and contexts are expected in the future to provide a more robust and reliable analysis of the perception of skin color.

Introduction

Smartphone users can easily create their own avatars as animated versions of emoji in augmented reality (hereinafter AR). An emoji mimics user's facial expressions. "Animoji" and "Memoji" provided by iPhone[1] or "AR emoji" by Samsung Galaxy[2] are the most popular services. Unlike more conventional and metaphorical representation using animals or other objects, humanoid characters have attracted a great deal of attention. Users create their own humanoid emoji for the use on many social platforms. This humanoid emoji ensures the user's privacy while bringing more fun to social communication.

When a humanoid emoji is created, the physical attributes in a digital photo are transformed into graphic images. The attributes mainly include shapes and colors of facial elements, hair styles, and facial expressions. During the transformation, shapes become more geometric and colors become more solid. Since humanoid emoji are fundamentally a balance of realistic precision and abstract schematisation, users anticipate a good level of resemblance from their humanoid emoji. Figure 1 illustrates the procedure whereby a user creates and utilizes the humanoid emoji using a smartphone. A selfie image is taken, image adjustments are made, and then the emoji is merged to form both static and moving images in real-time. We are motivated to examine how the humanoid emoji's skin color is decided and amended during the procedure. Hence, in this study, we have explored the notion of accurately transferring one's skin color from the digital portrait to the humanoid emoji.

In general, people respond to the change of their own skin color more sensitively than the color changes of other elements[3]. In fact, diversifying the emoji by providing alternative of skin colors have already been of great concern. Robertson and colleagues, for example, demonstrated that emoji users deliberately choose skin colors to avoid a negative representation of other users or groups[5].

For a discrete distinction of skin colors, emoji characters adopt the Fitzpatrick Scale and sort skin colors into six types[6]. In the case of humanoid emoji in AR, however, the stereotyped categorization is no longer valid. Instead, as displayed in Figure 2, smartphone users select one of the color patches and then refine it using the slide bar, until the simultaneously rendered emoji appears appropriately. Iterative adjustments are, therefore, inevitable until the rendered result appears to users' satisfaction.

In this circumstance, we attempted to figure out how peo-

Figure 1. *(left) Original digital picture (center) Being transformed into a humanoid emoji (right) The humanoid emoji for a casual representation of oneself.*

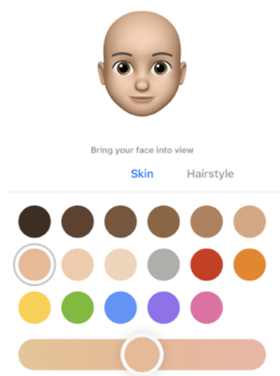

Figure 2. *Creating an emoji, smartphone users select one of the color patches and then refine it using the slide bar, until the simultaneously rendered emoji appear adequately. Hence, iterative adjustments are inevitable.*

ple perceive the facial skin color in digital portrait and humanoid emoji in AR contexts. We thus formulated two questions in the following: first, which facial regions should we refer to when defining the color of facial skin; second, whether the perception of human skin color is maintained or altered when a portrait image is transformed into an emoji in an AR context. To explore answers to the questions, we conducted a user study with graduate students majoring in industrial design. Quantitative and qualitative analysis was carried out.

Related Works

Skin color is one of the typical memory colors we are sensitive to[3]. Even tiny white balance adjustment on skin color brings different affective effects on digital portraits[4]. Driven not only by the cosmetic industry but also by the science of computer vision, a significant effort has been made to collect the true values of the skin color particularly focusing on the face. To capture the accurate skin color, spectrophotometers are facilitated to obtain the spectral reflectance from the skin surface. Regions such as the forehead, the nose tip, the cheeks and the chin are typical for data collection[7]. Studies have observed that the forehead region is the darkest whereas the cheek region is the lightest[7][8]. While in the cosmetic industry, the jawline is widely used to find the best match of foundation shade to make the base makeup appear natural[9]. In computer vision, skin color was extracted from the central region of a face and this region was regarded as a representative region[10]. The region selection was considered from a practical aspect that nonskin-colored features can be avoided in this region. Despite its importance, however, the representative skin color or facial region is still quite unclear.

Moreover, some studies have focused on a shift of skin color on digital media. When skin color is reproduced on digital media, it often turns out to be much brighter than optically measured values. For example, among the skin color data, the lightness of the North-East Asian is around 60 when measured with the spectrophotometer[10][11]. However, when they appear on a display, the lightness increases substantially[12]. Notably, we do not perceive this increase in lightness; rather we assume that the brightness is maintained. Zeng and Luo found that the preferred skin colors on digital media are more diverse in saturation, becoming paler or more vivid [12]. In the case of animation, as a kind of creation, skin colors are more extreme in lightness and saturation but also generally more homogeneous[13]. In this foregoing, research on the perceptual characteristics of facial skin color, for digital portrait and humanoid emoji in AR contexts, requires both an effective and affective approach.

Method

We conducted a user study to investigate how the color of facial skin was selected and altered depending on the media context.

Participants

A total of 20 graduate students (10 males and 10 females) in normal color vision participated in the user study. All of them held bachelor's degrees in industrial design and are currently enrolled in a graduate school majoring in industrial design. The participants were 25.75 years old on average, ranging between 21 and 32.

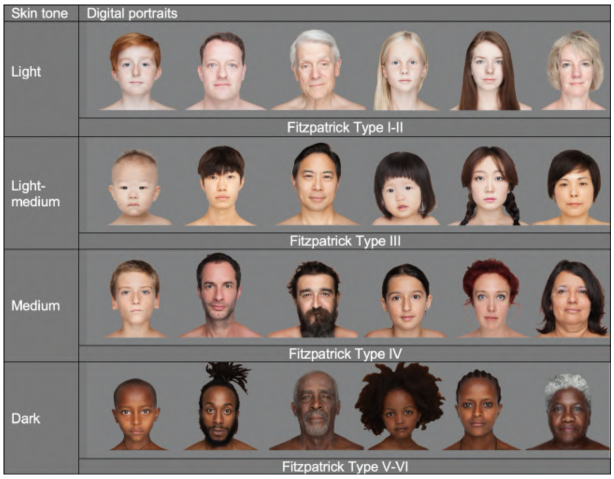

Figure 3. *The 24 digital portraits as stimuli.*

Stimuli: Digital Portraits

We prepared 24 digital portraits considering gender and age diversity as presented in Figure 3. The images were selected from the "Humanae Project" [15] and their copyright is owned by Angélica Dass who has been photographing people of every color since 2012. All images were downloaded from www.angelicadass.com. We sorted the portraits into four types of skin tone based on a modified Fitzpatrick scale[14]. Originally, the Fitzpatrick scale defines six types. We merged the brightest two types into "Light" and darkest two types into "Dark".

Procedure

The user study was conducted in an isolated room with a desk, a chair and a laptop computer. Participants were provided with Adobe Photoshop CC 2017. They were all fluent in using this graphic software. The study consisted of three task sessions and each task took around 30 minutes. After each task, participants took a 10-minute break. The details of the tasks are described below.

In Task A, each participant was instructed to find a color that best represented the facial skin of the digital portrait using an eyedropper tool. By clicking at a target region on the portrait with the eyedropper, the color of that pixel was applied to the circular patch below the portrait image (see "Task A" in Figure 4). Partic-

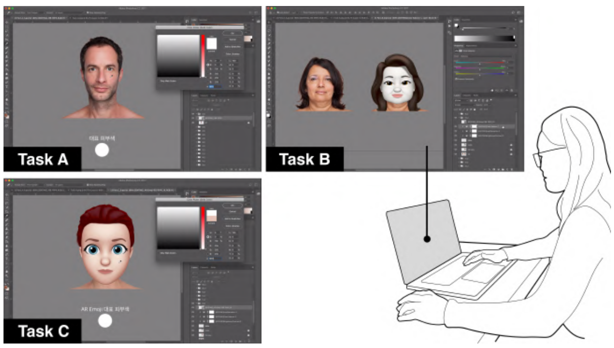

Figure 4. *Three tasks were given to the participants.*

ipants were allowed to change the color until they were satisfied and spent as much time to do so as they needed. All participants were exposed to the entire 24 images, and the images were presented randomly. When the color selection was made, the images were recorded for the data analysis.

In Task B, we prepared humanoid emojis using the Memoji from Apple iOS 12. Participants were presented with a digital portrait and an emoji in a rendered white mask with natural highlight and shadows for skin region. They were instructed to color the emoji skin mask until it was perceptually matched with the digital portrait. Participants were allowed to use three functions of image adjustment to adjust the color of the skin mask: brightness/contrast, color balance and hue/saturation. Participants worked on the 24 images and spent as much time as was necessary.

Finally, in Task C, participants opened the emojis that they created during the previous task. Only the colored humanoid emoji was presented. The technical process was identical to that of Task A, and thus each defined representative skin colors for the 24 humanoid emojis. Figure 4 illustrates examples of the three tasks prepared for the participants before editing.

Results

For each digital portrait, we obtained 20 representative skin colors of digital portraits, completed humanoid emoji in AR and corresponding representative skin colors of humanoid emoji. All color values were extracted from Adobe Photoshop CC 2017 and recorded with L*, a*, and b* in CIELab color space. In terms of CIELab color space, it has a stronger advantage in describing the color differences and the amount of color changes due to its perceptual uniformity. L* is for the lightness, a* and b* are for the green–red and blue–yellow color components and C* is the chroma, calculated based on a* and b*.

Representative Region

Facial skin colors are not uniform. Understanding where and how people recognize facial skin colors is important for practical use. Therefore, in order to extract the representative region, we first averaged both representative color and completed humanoid emoji for each digital portrait. For every digital portrait and averaged humanoid emoji, we then extracted the pixels that matched with the representative skin color using MATLAB®.

In Figure 5, skin pixels matching with the average representative skin color with $\Delta E^* < 10$, are shown in color. The smaller the ΔE^*, the clearer the color. By observing the extracted pixels, we observed two regions where the pixels appear most for two contexts.

$$\Delta E = \sqrt{\left(L_2^* - L_1^*\right)^2 + \left(a_2^* - a_1^*\right)^2 + \left(b_2^* - b_1^*\right)^2} \quad (1)$$

First is the forehead rim. In the shape of an ellipse, the distance between two centers of each brow determines the length of the major axis and the distance between the center of the brow and the propagation determines the length of the minor axis. Second is the linking band between eye and lip. The shape of the band follows the contour of cheek. It starts from the outside corner of the eye and ends at the corner of the mouth. When we view the human face and identify the facial skin color, therefore, the forehead rim or a linking band between eye and lip could be considered as the representative region. This applies to both photography and illustration such as humanoid emoji.

Color Difference

To analyze the perceptual quantity of color choices and differences, we calculated the ΔE, the Euclidean distance between the representative skin color of the portrait image and the designed humanoid emoji based on L*, a* and b* values.

During Task B, in theory, the representative skin colors in both the portrait image and its humanoid emoji should have been perceptually identical to each other. Accordingly, we compared the color patches from Task A with those of Task C, to examine the color difference. Figure 6 presents examples of paired comparison across the four skin tones. An increase of lightness is observed in the light to medium skin (examples are (a), (b) and (c) in Figure 6), confirming the previous study on skin color reproduction for animation addressed a color shift [13] [12]. Conversely, the humanoid emoji becomes darker ((d) in Figure 6), implying the color shift needs to be further investigated involving a wider range of ethnic groups.

To statistically examine the color differences, we performed a paired samples t-test on L*, a*, b*, and C* values among the four skin tones. The statistical results are summarized in Table 1. Since the "Mean difference" is a subtract of Task C from Task A, the positive ΔL*, Δa*, Δb* and ΔC* indicated brighter, more reddish, more yellowish and more vivid tones, respectively, while being transformed from a digital image portrait to a humanoid emoji. Thus, in the "Light" skin tone category, on average, the skin colors of humanoid emoji are brighter ($\Delta L^* = 3.16$), less reddish ($\Delta a^* = -1.76$) and less saturated ($\Delta C^* = -1.09$). These color shifts were statistically significant at 95% confidence level ($p < 0.05$).

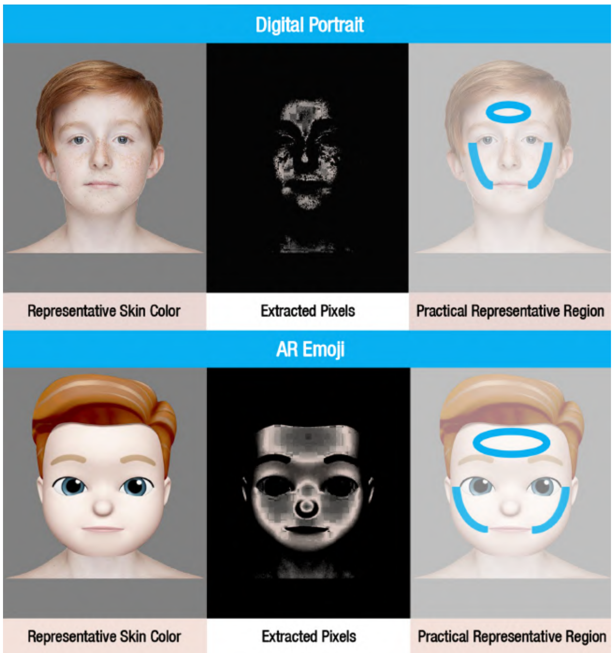

Figure 5. Example of extracted skin pixels where the representative color was matched.

Color differences between digital portraits and humanoid emoji in AR. For the statistical comparisons, paired-samples t-tests were performed. (N = 20, 24 images in total)

Skin tone	Feature	Mean difference[a]	t[b]
Light	$\Delta L*$	3.16	8.67*
	$\Delta a*$	-1.76	-5.91*
	$\Delta b*$	0.00	0.00
	$\Delta C*$	-1.09	-2.80*
	Color	Portrait	Emoji
	$\Delta E*$	6.48	
Light-medium	$\Delta L*$	2.95	6.33*
	$\Delta a*$	-2.07	-6.52*
	$\Delta b*$	-1.78	-4.14*
	$\Delta C*$	-2.49	-5.13*
	Color	Portrait	Emoji
	$\Delta E*$	7.68	
Medium	$\Delta L*$	3.24	4.78*
	$\Delta a*$	-2.81	-7.75*
	$\Delta b*$	-0.77	-1.91
	$\Delta C*$	-2.34	-4.79*
	Color	Portrait	Emoji
	$\Delta E*$	9.10	
Dark	$\Delta L*$	-2.26	-3.07*
	$\Delta a*$	-2.30	-5.68*
	$\Delta b*$	-1.02	-1.77
	$\Delta C*$	-2.24	-3.38*
	Color	Portrait	Emoji
	$\Delta E*$	10.21	

[a] refers to difference subtracting the color values of humanoid emoji in AR from those of digital portrait.

[b] t scores from paired sample t-test to statistically examine the mean difference, df = 19.

* $p < 0.05$.

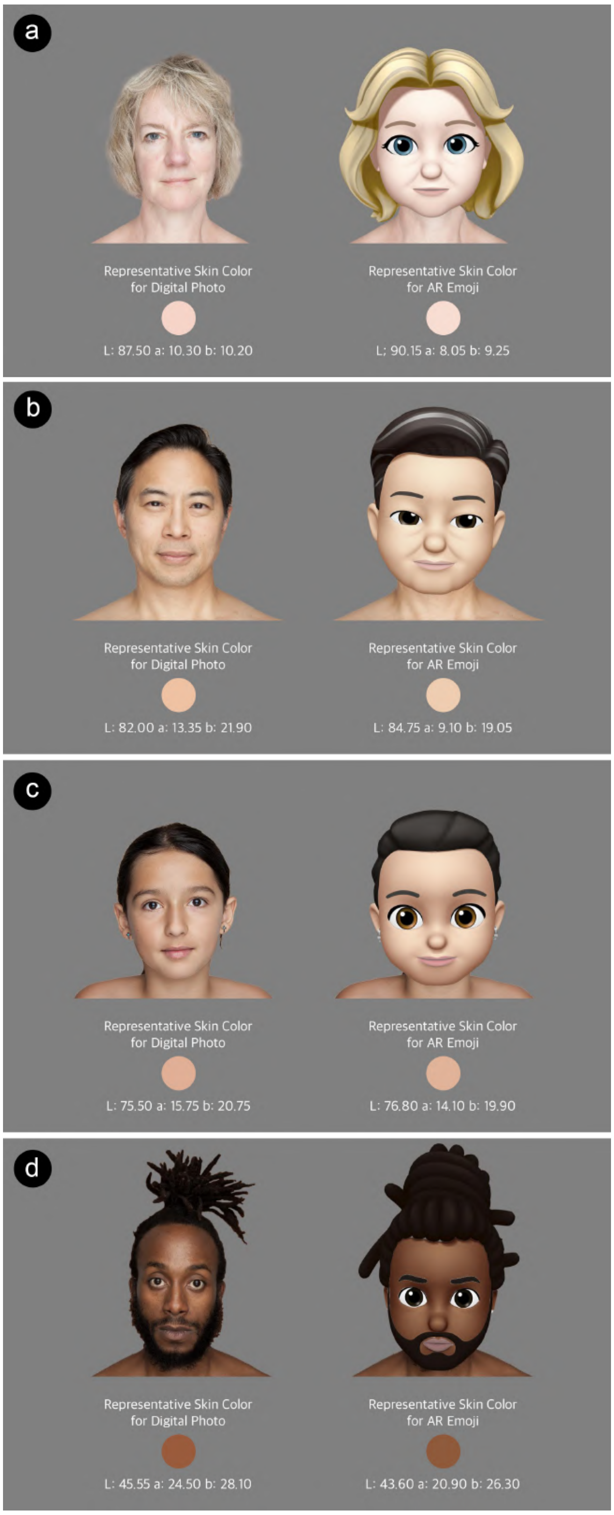

Figure 6. *Paired comparison between task A and task C across the four skin tones, pairs belong to a: light skin tone; b: light-medium skin tone; c: medium skin tone; d: dark skin tone.*

Concerning the chroma change, a different tendency was revealed from that of the previous study, in which skin colors become more vivid in digital graphics [13]. In our study, a decrease of chroma was observed throughout the four skin types. As the paler tendency was found across the tone levels, we consider this as the difference between humanoid emoji from the conventional digital graphics. Hence, the ΔC* scores were negative for all and the differences were also statistically significant. In addition to the statistical significance, we conclude the color shifts were fairly visible, since for color difference, ΔE* values were bigger than 2.3. In the human perception of color, when two colors have a larger difference than ΔE* of 2.3, it exceeds just noticeable difference (JND) [16].

Discussion

Through the user study, we found out that users anticipate a lighter color when a portrait is transformed into a humanoid emoji in AR. Reportedly, digital skin color is usually lighter than optically measured actual skin color[12], and indeed, a lighter skin tone appeared in the humanoid emoji in our study. However, in the case of dark skin tones, the tendency did not follow the general tendency. Compared to the studies on the medium to light range of skin tone, the dark range has not yet been investigated. This implies that skin color studies need to be specified to find adequate answers regarding the human perception of dark skins. At the same time, we must acknowledge that the survey was answered by the Korea population only. Their limited experience of evaluation of dark skin tones, may have influenced the result. In other words, the perception of one's skin color may be dependent on the ethnicity of a person who makes the judgment. In terms of vividness change, the colors of humanoid emojis are paler than the digital portraits in all skin types. This indicates that the saturation of emojis needs to be reduced to achieve a natural appearance more akin to the selfie.

Concerning the skin color representative regions, we derived two areas through the image analysis. When we view a human face and identify the facial skin color, the colors are converged in the cheek region, and especially the linking band between eye and lip. The color from the representative region has potential for versatile uses. For example, when designers edit the skin color of a portrait image, more attention needs to be paid to this region. The finding of cognitive representative regions of facial skin color is meaningful in providing insights or directions for related applications. The skin representation region is particularly of interest to the cosmetic industry, and objective evidence will be in high demand. Facilitating tools such as eye-tracking equipment, it can be further investigated.

This study reflects the subjective judgments of Korean people only, and thus the findings are currently limited to the perception of Koreans. The judgment of skin color can be influenced by the ethnicity membership to which the evaluators are more familiar with; we admit this limitation of the present study. Nonetheless, this study has figured out the aligned and dis-aligned tendency of the perception of skin color between portrait images and their humanoid emoji. The empirical finding can contribute to the implementation of AR-based solutions in multiple industries. By expanding the subject groups considering ethnic diversity, more evidence is collected to form a data set utilized in the graphical representation of perceptually satisfactory skin colors.

Conclusion

The study explored the ways in which people perceive facial skin color in two contexts: digital portraits and humanoid emoji in AR. A user study was conducted with 20 graduate students majoring in industry design. Participants decided the representative skin color for 24 digital portraits, designed a humanoid emoji facial skin mask suitable for the person in the digital portrait, and finally determined the representative skin color for humanoid emoji. Results indicate that the forehead region, and cheek region, particularly the linking band between eye and lip, could be considered as representative regions in skin color cognition. Furthermore, the color difference between two contexts is also clarified. A lighter skin tone is manipulated for light and medium skin colors while a darker skin tone is manipulated for dark skin colors when a portrait is transformed into humanoid emoji. Skin colors are paler across all skin types. In the future, we will expand our user study to include participants from different countries and provide more detailed guidelines of skin color utilization in diverse digital applications.

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