Identification of Factors Related to the Enhancement of Image-Quality for Subjective Image-Quality Assessment Model Based on Psychological Measurement

Eriko Aiba[1], Koyu Numata[1], Takashi X. Fujisawa[2], and Noriko Nagata[1]
[1]Graduate School of Kwansei Gakuin University, Hyogo, Japan,
[2]Nagasaki University, Nagasaki, Japan,
eaiba@kwansei.ac.jp

Abstract. **The purpose of this study is to identify the physical factors affecting image-quality for a comprehensive enhancement in subjective image-quality assessment by human being. In recent years, digital cameras have become extremely popular because they enable image recording with very high fidelity and are affordably priced. However, in subjective image-quality assessment by human, one does not always consider that images with high fidelity are of high quality. In this study, a psychological experiment was performed as the first step to develop a subjective image-quality assessment model that considers *kansei* of human being by using conjoint method. We particularly focused on the identification of physical factors without depending on a scene. The results of this experiment showed that "luminance" and "contrast" may contribute to an enhancement in the image-quality assessment, regardless of the type of scene used. It was also suggested that human memory, in which the colors preferred by the individual are retained, also plays a major role in a subjective image-quality assessment.**

***Keywords*: Image-quality, *Kansei*, Psychological factor, Physical factor, Subjective assessment**

I. Introduction

In recent years, digital cameras have become extremely popular because they enable image recording with very high fidelity (little noise or distortion) and are affordably priced.

However, in subjective image-quality assessment by human being, one does not always consider that images with high fidelity are of high quality. Instead, one tends to assume that the image-quality is enhanced by distortion or that the texture of the object is well reproduced upon the addition of noise to the image [e.g., 1]. It has also been reported that the color fidelity can enhance assessment when color saturation is higher than the actual color intensity [2].

Hence, improvement in physical fidelity does not always result in enhancement in image-quality assessment by human being, and the actual indicators of image-quality still need to be identified. Furthermore, there are very few studies on the development of image-quality assessment model for digital images that is based on the *kansei* of human being to be perceived as "beautiful," "preferable," or "good" [3], although studies based on encoding methods have been frequently carried out to assess the performance or image-quality in the case of displays and printers [4-5].

Therefore, in this study, we set it a final goal to identify the physical factors affecting image-quality for a comprehensive enhancement in subjective image-quality assessment by human being. A psychological experiment was performed as the first step to develop a subjective image-quality assessment model that considers the abovementioned *kansei* of human being. In particular, we focused on the identification of physical factors that contribute to enhance subjective image-quality assessment, without depending on a scene.

II. Previous Study

Image-quality refers to the quality of a visual image, and its assessment is deeply affected by the psychological factors of human being. Therefore, it is necessary to elucidate the relationship between various physical factors such as noise level, saturation and luminance, and psychological factors such as sense of reality, sharpness and brightness, and then to develop a subjective image-quality assessment model, in order to assess image-quality comprehensively.

While over a number of years many studies have been carried out on the development of image-quality assessment models, with the aim to improving the quality of analog images and the performance of displays and printers, very few studies have been conducted to develop subjective image-quality assessment models for digital images. In addition, digital images are stored in various types of media, and hence, it is essential to enhance the assessment of digital images themselves by developing a subjective image-quality assessment model for digital images.

There are two main types of image-quality assessment methods: (1) the objective assessment method based on the measurement of physical quantities and (2) the subjective

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(a) Portrait

(b) Bridge (Landscape1)

(c) Castle (Landscape2)

Fig. 1. Original images

assessment method based on psychophysical methods [2]. With regard to the former method, there are especially a large number of researches being carried out for the assessment of compressed image data such as JPEG and MPEG data and for the determination of the optimal physical quantities for such an assessment. In addition, this method has been employed for the development of image-quality assessment systems, which in turn are used to enhance the quality of medical images. In some previous studies, many assessment theories have been proposed by applying indicators such as luminance contrast, modulation transfer function (MTF) and noise level [e.g., 6-7].

As for the latter method, there are some studies that found the effect of memory on texture and color fidelity, and others that showed the effects of "sharpness" and "intensity" on image-quality assessment through the extraction of the psychological factors that affect image-quality assessment based on Semantic Differential method [e.g., 2, 8].

Although, in both the aforementioned studies, the final goal is to integrate objective assessment and subjective assessment, the relationship between physical factors and psychological factors still to be identified.

Therefore, in this study, we elucidate the relationship between the physical and psychological factors related to image-quality assessment and investigate the influence of high sensitivity on these factors. At that time we aim to develop an image-quality assessment model based on the subjective assessment of image-quality by human being.

III. EXPERIMENT

A. Method

Besides noise level, saturation, and luminance, there are several other physical factors that affect image-quality assessment, such as color, gradation and texture. In this experiment, we consider four typical physical factors, i.e. luminance, saturation, contrast, and sharpness, which are common and quantitatively varied easily by using popular image processing software, and investigated the effect of these factors on subjective image-quality assessment, which is based on the choice of "good/preferable."

B. Participants

The participants were 14 men and 3 women in their twenties, who declared that they had no vision disorder.

C. Stimuli

The three scenes shown in Fig. 1 were used for the stimulation: "(a) Portrait," "(b) Bridge (Landscape1)" and "(c) Castle (Landscape2)." In this experiment, two types of landscapes were used to determine the factors of scene dependence as well as the factors of very weak scene dependence. Four levels were set for each of the four physical factors—luminance, saturation, contrast, and sharpness—as shown in Table 1. These levels were the minimum values to which the experimenters could give a rank based on their visual comparison while ensuring that images would not be too visually unnatural.

TABLE 1: FACTORS AND LEVELS.

Factors	***Levels***			
Luminance	-12%	0%	12%	24%
Contrast	-12%	0%	12%	24%
Saturation	-12%	0%	12%	24%
Sharpness	Used	Not used	Outline only	

TABLE 2: CONJOINT CARD.

No.	***Luminance***	***Contrast***	***Saturation***	***Sharpness***
1	24%	0%	12%	Outline only
2	0%	-12%	0%	Outline only
3	24%	-12%	24%	Used
4	24%	24%	-12%	Not used
5	-12%	0%	0%	Not used
6	12%	0%	24%	Not used
7	12%	-12%	12%	Not used
8	24%	12%	0%	Not used
9	12%	12%	-12%	Outline only
10	-12%	24%	24%	Outline only
11	0%	24%	12%	Not used
12	12%	24%	0%	Used
13	-12%	12%	12%	Used
14	-12%	-12%	-12%	Not used
15	0%	12%	24%	Not used
16	0%	0%	-12%	Used
17	0%	-12%	-12%	Not used
18	12%	-12%	12%	Outline only

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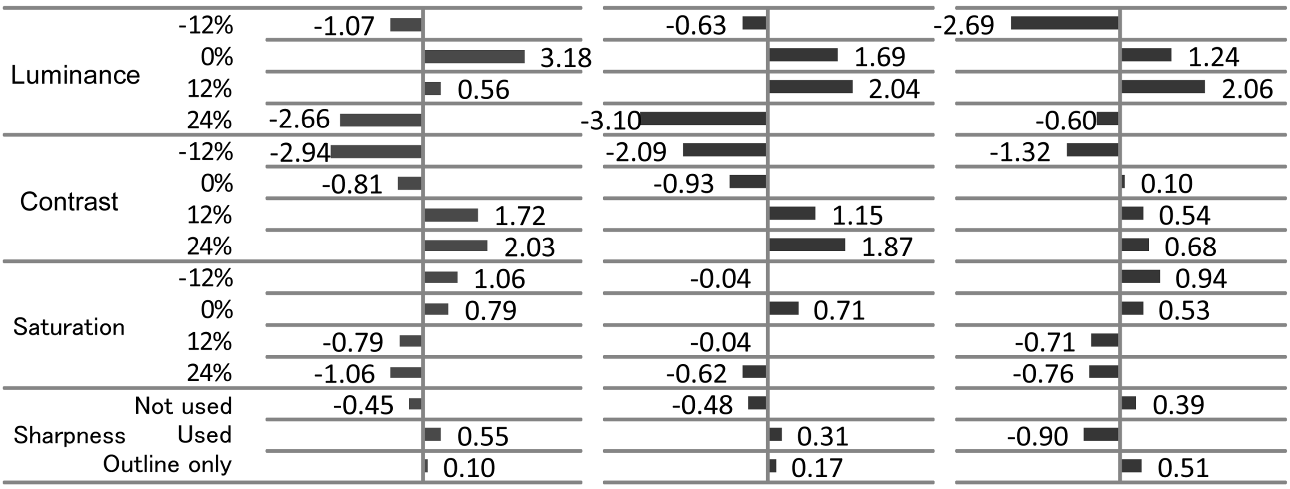

(a) Portrait (b) Bridge (Landscape1) (c) Castle (Landscape2)

Fig. 2. Part worths.

However, if all combinations of the aforementioned levels were to be used, 192 (4 × 4 × 4 × 3) photographs would have to be compared.

Comparison of such a large number of photographs would be tedious and time-consuming; moreover, accurate assessment may not be possible because of excessive mental stress. Therefore, we adopted a conjoint analysis method, which is an orthogonal design method, to decide the appropriate combinations of the parameters at each level. By using this method, we could generate 18 combinations (Table 2) for each scene. On the basis of these combinations, we processed the three scenes using Photoshop CS2 and generated 18 assessment images for each scene.

In this experiment, we prepared hard copies of the images to compare the image-quality of 18 photographs for each scene. To solve the color management problem caused by differences in color space in the hard copies, we printed the images on a 2L-size gloss photo paper using an industrial printer (QSS-3502, Noritsu Koki, Co., Ltd.), as this helped minimize the aforementioned difference.

D. Procedures

The 18 photographs for each scene were laid out on a sufficiently large white desk, and the participants were asked to place the photographs, in the order of the "better/more preferable" from top to bottom for each scene. The average illuminance in the room used for the assessment was 612 lx. To avoid the shadow effect, the participants were instructed to get up and assess the images so that they could get a clear view of all the photographs.

IV. Results

A. Importance of each factor

Table 3 shows the importance of each of the four factors (in percentage) for each scene. A higher value indicates that the given factor is of more importance in the scene.

The results revealed that the degree of importance was in the order luminance > contrast > saturation > sharpness for any of the scenes. "Luminance" was shown to be outstandingly more important than other factors for the "better/more preferable" selection in the "Portrait," "Bridge," and "Castle" scenes used in the experiment.

TABLE 3: IMPORTANCE OF EACH FACTOR.

Scenes	*Luminance*	*Contrast*	*Saturation*	*Sharpness*
Portrait	40.88	29.10	18.06	11.97
Bridge	42.91	22.59	21.75	12.75
Castle	42.01	30.09	17.48	10.42

B. Part worths

Fig. 2 shows the part worth of each factor. Part worth is the coefficient of the contribution of each level to each factor, and the sum of the part worth values for all levels for a given factor is 0. The part worth values in this experiment indicate the effect of each level on each factor when the participants select "better/more preferable" photographs. A positive value indicates that the given level facilitates the "better/more preferable" selection, while a negative value indicates that the given level inhibits the "better/more preferable" selection.

We found that luminance levels 0% and 12% facilitated the "better/more preferable" selection in all the scenes. Since the level of contrast was high in all the scenes, the "better/more preferable" selection was facilitated. At low levels of saturation, the "better/more preferable" selection was facilitated for Portrait and Castle, while 0% saturation was preferable for this selection in the case of Bridge. The sharpness level "not used" inhibited the "better/more preferable" selection for Portrait and Bridge, but the "used" level facilitated the "better/more preferable" selection for Castle.

V. Discussion

In all the scenes, the degree of importance was in the order of luminance > contrast > saturation > sharpness, and "luminance" was outstandingly more important than the other factors. Therefore, there is the possibility that the participants sensitively reacted to changes in luminance when selecting "better/more preferable" photographs.

The part worth values of luminance indicate that it suppresses the "better/more preferable" selection when

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reduced to -12% or increased to 24%, for all the scenes. A 12% increase in luminance facilitates the “better/more preferable” selection, whereas a decrease in luminance to -12% does not. On the basis of this fact, we assume that the image-quality is assessed as “better/more preferable” when luminance is set to a relatively high value within a range that is not unnatural. However, 0% luminance facilitates the “better/more preferable” selection only for Portrait. It suggests that the human skin, which is visible only in the case of Portrait, has a marked effect on this result. Skin is one of the most familiar objects for us, and its color has a unique name as “skin color”. Therefore skin color is clearly conceptualized in our memory. In fact, in previous studies, it has been indicated that the most preferable skin color varies depending on the age and gender of the object [9]. It is likely that in the portrait of a young woman used in this experiment, the “better/more preferable” selection is most strongly preferred at 0% luminance, as the skin color in this case is the “best/most preferable.”

Contrast facilitated the “better/more preferable” selection because its level was high in all the scenes. Therefore, we could not determine the peak of the worth value within the contrast range used in this experiment. However, since the peak value could not be determined for any of the scenes, it indicated that the “better/more preferable” selection was facilitated in the case of images with high contrast, as revealed by image-quality assessment without object dependency.

There was no common trend in saturation and sharpness among the three scenes, and the degree of importance of these two factors was not as high as that of luminance or contrast; hence, we assumed the effects of sharpness and saturation to be relatively weak.

On the basis of the abovementioned observations, we found that the effects of “luminance” and “contrast” were more prominent among those of the four physical factors used in this experiment and that subjective image-quality assessment for “better/more preferable” selection could be enhanced by appropriate manipulation of these factors.

VI. Conclusion

In this study, we attempted to identify the physical factors affecting image-quality in subjective image-quality assessment and performed psychological experiments, with the final goal of developing a subjective image-quality assessment model that considers *kansei* of human being; the use of such a model may help enhance the comprehensive quality of digital images.

The results of this study revealed that among the physical factors considered, “luminance” and “contrast” may contribute to an enhancement in the image-quality assessment, regardless of the type of scene used. Further, memory information such as color intensity plays a vital role in subjective image-quality assessment including a high level *kansei* such as “better/more preferable”.

The results of many previous studies show that color preferences depending on cultural influences, including the environment in which the individual (assessor) grew up; thus, we state that human memory, in which the colors preferred by the individual are retained, plays a major role in subjective image-quality assessment [10]. Therefore, it is also important to take into account various types of human attributes when constructing the subjective image-quality assessment model. In the future, we plan to verify not only the relationship between the physical factors and psychological factors but also the relationship between these results and *kansei* and attributes of individuals, and use this information to construct a model that can help identify the optimal image-quality on the basis of individuals’ preference.

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