The roles of color lightness and saturation in inducing the perception of miniature faking

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Abstract— **The miniature faking effect is a perceptual phenomenon where life-sized objects and landscape in tilt-shift photographs are perceived to be miniature. Previous studies have contributed to the generation of miniature faking; these include blur (bokeh), camera angle, vantage point, and perceived distance. Although color has also been considered to be a crucial factor in inducing the miniature faking effect, research based on systematical manipulations of color attributes has not been conducted. In the present study, we conducted two experiments, namely, paper-based and display-based to control the color lightness and saturation of two bird's-eye view photographs. The results showed that the rated miniature faking effect is dependent on alterations of color lightness and saturation. Higher saturation, whereas lower lightness was found to enhance the miniature faking effect. These results demonstrated the crucial role of color in inducing the perception of miniature faking and further provided new materials to explore the general cognitive mechanism involved in miniature faking.**

Keywords: Miniature faking; tilt-shift miniaturization; color; saturation; lightness; image processing; photography

I. INTRODUCTION

The miniature faking effect, which is also referred to as the diorama effect or diorama illusion, is a phenomenon related to the visual perception of photographs where real objects and life-sized landscape are perceived to be miniature. Miniature faking can be produced by special photography techniques when using a tilt-shift lens or by the digital post-processing of an ordinary photograph. Consequently, it is also referred to as tilt-shift miniaturization. A sample of such a photograph is depicted in Fig. 1.

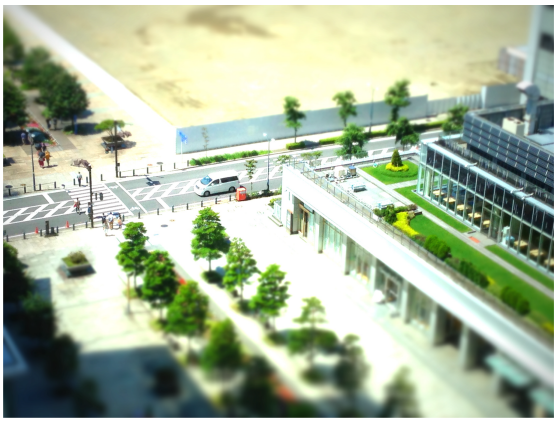

Figure 1. An example of miniature faking. A photograph of a real scene but perceived as a diorama.

Several psychophysical inducing factors have been revealed in previous studies so as to determine the reasons for miniature faking. Blur, also known as *bokeh,* which linearly appears at the top and bottom of a photograph, has been considered to be an essential factor in miniature faking [1]. The effect of blur has been explained from the perspective of distance perception [1, 2, 3]. Camera angle, corresponding with vantage point, has been reported to be another factor involved in miniature faking [4, 5]. Previous studies have also revealed other factors such as depth perception [3, 4], photograph size [4], and density of objects [5]. Besides the psychophysical factors noted above, the role of color has also been indicated to be an important factor in inducing the miniature faking effect [4, 5, 6]. In our previous investigation, factor analysis revealed color to be a latent variable underlying the miniature effect [5]. An experimental manipulation on color and blur also suggested that strengthened chroma helped to induce a more enhanced miniature faking effect [6]. However, as yet, no experiments involving systematical manipulations on multiple color attributes have been conducted. In the present study, we altered color lightness and saturation to explore the relationship between different color attributes and the miniature faking effect.

II. EXPERIMENT 1

A. Methods

1) Participants

The participants in the experiment included 28 adults (15 males and 13 females; 21–59 years old, mean ± *SD* age: 27.1 ± 9.3 years). All participants had normal or corrected-to-normal visual acuity. They were unaware of the purpose of the experiment.

2) Stimuli

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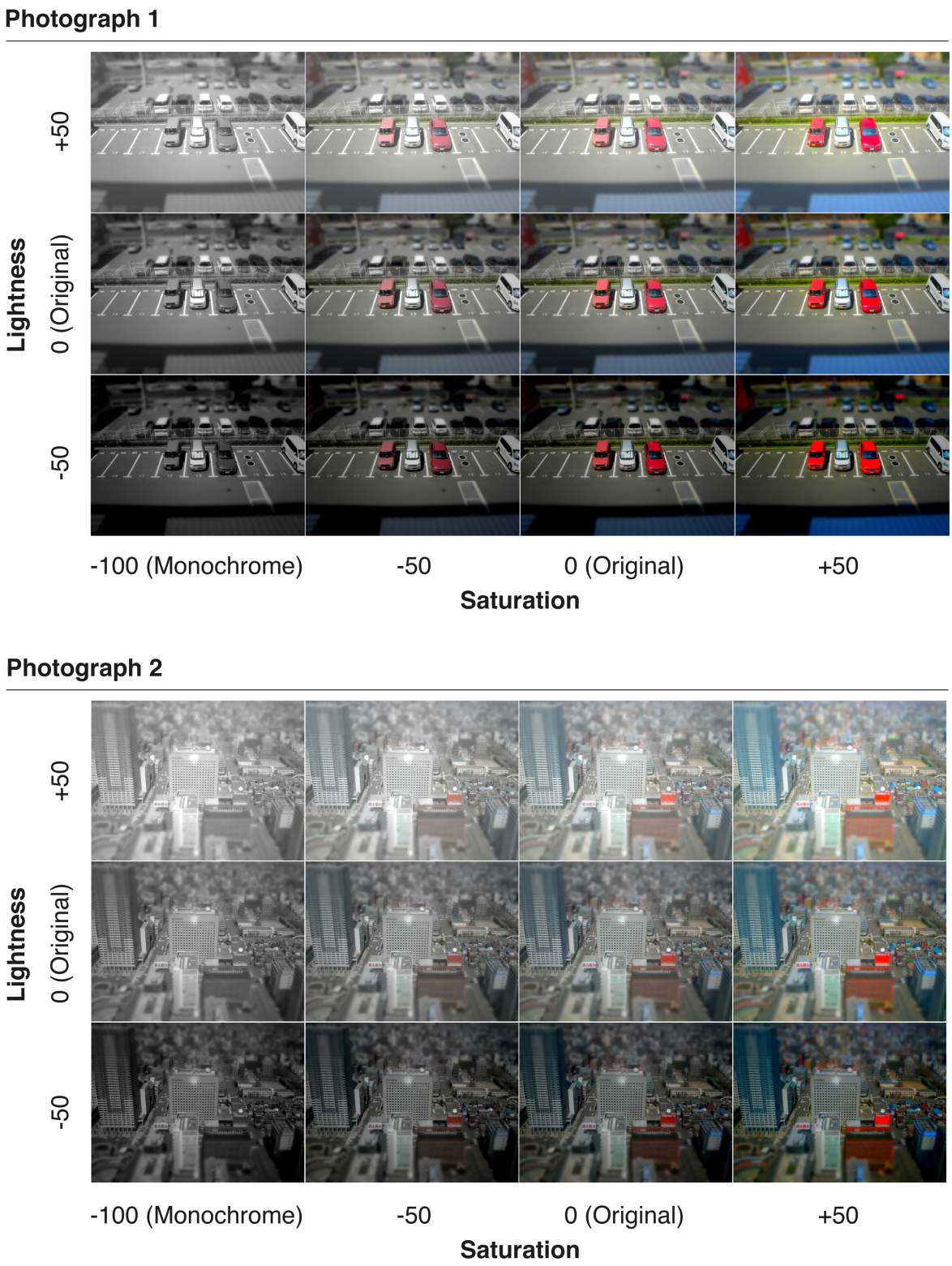

Figure 2. Stimuli used in the experiments. A total of 24 stimuli were recreated based on two bird's-eye view photographs with manipulations on saturation in four levels and lightness in three levels.

As shown in Fig. 2, two photographs with a bird's-eye view of urban scenery in Japan were used as original images in the experiment. It is noteworthy that all the participants lived in Japan.

We manipulated each original image's saturation on four levels and lightness on three levels by using TiltShift Generator, an Adobe AIR based image processing software for recreating tilt-shift as well as miniature faking effects on normal photographs. The

image processing was conducted by employing a desktop computer (VAIO, SONY, Japan).

Regarding the manipulation of saturation, we adjusted the saturation indicator in the software to +50, 0 (original), -50, and -100 (turned to monochrome). Furthermore, in relation to lightness, we adjusted the brightness indicator to +50, 0 (original), and -50. Consequently, 24 images, including the original images, were created. We also used a linear blur filter with a strength value of +0.3 to 25% of the areas at the top and bottom of all the images by adjusting the vignetting strength to a value of 0.3 to generate a miniature faking effect. The size of the processed images was 1500 and 2000 pixels in height and width, respectively. All 24 images were employed as stimuli in the experiment.

We printed the stimuli on A5-sized (148*210 mm) white paper in RGB color mode by using a four-color inkjet printer. The stimuli were printed at the center of the paper, with a size of 128*170 mm. We printed one stimulus onto each sheet of paper; hereinafter referred to as the stimulus sheet.

3) Procedure

The participants were asked to view the stimulus sheet and rate the miniature faking effect on a 7-point scale, ranging from *"do not look like miniature"* (1) to *"look like miniature"* (7). The 24 stimulus sheets were each tested randomly without repetition. No time limits for the participants' viewing or rating of the photos were imposed. However, they were instructed to respond intuitively, without any thoughtful judgment.

B. Results

We conducted a three-way within-participant analysis of variance (ANOVA) on the mean rated values of the miniature faking effect by employing the factors, stimulus, saturation, and lightness. The results of ANOVA revealed a significant main effect of saturation [$F(3, 81) = 10.310$, $p < 0.0001$] as well as a significant interaction between saturation and lightness [$F(6, 162) = 2.947$, $p < 0.01$]. However, the main effect of stimulus [$F(1, 27) = 1.308$, $p = 0.263$], the main effect of lightness [$F(2, 54) = 1.284$, $p = 0.285$], the interaction between stimulus and saturation [$F(3, 81) = 0.433$, $p = 0.730$], the interaction between stimulus and lightness [$F(2, 54) = 2.388$, $p = 0.101$], and the interaction among three factors [$F(6, 162) = 1.01$, $p = 0.421$] were not significant. Tests of simple main effects on the significant interaction between saturation and lightness showed that the effect of saturation was significant for all lightness conditions [Original: $F(3, 243) = 6.089$, $p < 0.001$; +50 lightness: $F(3, 243) = 14.598$, $p < 0.0001$; -50 lightness: $F(3, 243) = 2.682$, $p < 0.05$]. However, the effect of lightness was significant only when the saturation was enhanced [Original: $F(2, 216) = 1.618$, $p = 0.201$; +50 saturation: $F(2, 216) = 5.259$, $p < 0.01$; -50 saturation: $F(2, 216) = 0.436$, $p = 0.647$; -100 saturation: $F(2, 216) = 1.742$, $p = 0.178$]. Multiple comparisons were conducted by using Ryan's method [7]. Regarding the significant main effect of saturation, there were significant differences between +50 saturation and the original, between +50 and -50 saturations, and between +50 and -100 saturations (ps < 0.01). Regarding the significant interaction between saturation and lightness, when the lightness was original, the differences between +50 and -50 saturations, and between +50 and -100 saturations were significant (ps < 0.001); When the lightness was enhanced (+50), the differences between +50 and original saturations, between +50 and -50 saturations, and between +50 and -100 saturations were significant (ps < 0.001). When the lightness was diminished (-50), the difference between +50 and -100 saturations was significant ($p < 0.01$).

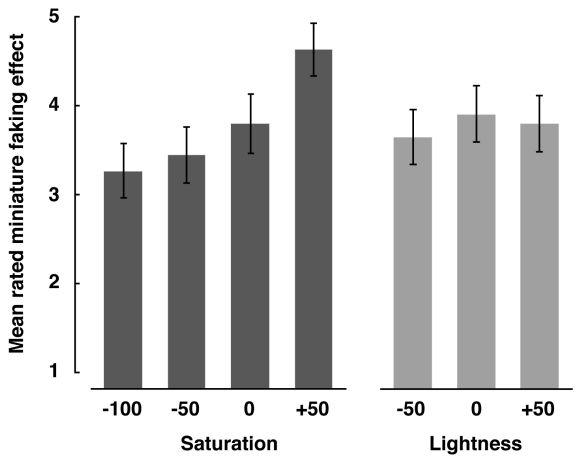

Figure 3. Results of Experiment 1. The mean rated miniature faking effects are shown as functions of saturation and lightness. Error bars denote SEM of the mean.

Based on the significant main effect of saturation, we plotted the rating values of miniature faking averaged over the 28 participants as a function of saturation (Fig. 3). It is evident that the miniature faking effect was strengthened by manipulations of higher saturation. The rating values as a function of color lightness were also plotted in Fig. 3.

C. Discussion

In Experiment 1, we manipulated the color lightness and saturation of two bird's-eye view photographs, which were recreated as tilt-shift photographs. The role of saturation was clarified by a significant main effect revealed from ANOVA. However, the function of color lightness remained unclear because as shown in Fig. 3, the rated miniature faking effect seemed to be similar among different lightness conditions. One possible reason is that Experiment 1 was conducted by using stimuli printed on paper (surface color) while the color lightness of stimuli was adjusted by using a computer display (luminous color). Another possible reason was the small sample in Experiment 1. Consequently, we conducted an online survey in Experiment 2; all the stimuli were presented through display devices and more participants were recruited.

III. Experiment 2

A. Methods

1) Participants

The participants included 250 people who were recruited online through Yahoo! Crowdsourcing. Of

these, 237 participants (155 males and 82 females; 12–68 years old, mean ± *SD* age: 43.4 ± 10.1 years) completed the experiment. The purpose of the experiment was not revealed to the participants beforehand.

2) Stimuli

We used the same 24 images, which were employed in Experiment 1, as stimuli. However, considering the universality of an online experiment, the resolution of the images was compressed to 1000*750 pixels. The image processing was conducted by using a desktop computer (iMac Pro, Apple, California) with Adobe Photoshop CC 2019. The manipulations of saturation and color lightness were those used in Experiment 1.

3) Procedure

The script for Experiment 2 was created by using jsPsych [8] and then uploaded to an online survey website operated by us. Participants recruited from Yahoo! Crowdsourcing were guided to access our website to participate in the experiment.

After obtaining informed consent and collecting demographic data, the experiment started with five practice trails in which stimuli were randomly selected from the 24 images. The same method of rating with the exception of rating values being changed from 1–7 to 0–6 was employed. The value, 0 meant no miniature faking effect. In addition, rating scales were replaced by buttons with numbers to accommodate those participants who used tablets and smartphones. After the practice trails, each of the 24 stimuli was tested randomly without repetition. No time limits were imposed for either the observation or response periods. Some additional information was provided after the experiment trials to help the participants obtain rewards via Yahoo! Crowdsourcing.

B. Results

In accordance with Experiment 1, a three-way within-participant ANOVA was conducted on the mean rated values of the miniature faking effect with the factors, stimulus, saturation, and lightness. In accordance with the results of Experiment 1, the main effect of saturation [$F(3, 708) = 91.872$, $p < 0.0001$], and the interaction between saturation and lightness [$F(6, 1416) = 2.192$, $p < 0.05$] were revealed to be significant. In addition, the main effects of stimulus [$F(1, 236) = 19.908$, $p < 0.0001$] and lightness [$F(2, 472) = 8.775$, $p < 0.001$] were also significant. However, the interaction between stimulus and saturation [$F(3, 708) = 0.522$, $p = 0.668$], the interaction between stimulus and lightness [$F(2, 472) = 1.854$, $p = 0.158$], and the interaction among the three factors [$F(6, 1416) = 1.442$, $p = 0.195$] were not significant. Tests of simple main effects on the significant interaction between saturation and lightness demonstrated that the effect of saturation was significant for all the lightness conditions [Original: $F(3, 2124) = 50.549$, $p < 0.0001$; +50 lightness: $F(3, 2124) = 44.027$, $p < 0.0001$; -50 lightness: $F(3, 2124) = 55.292$, $p < 0.0001$]. However, the effect of lightness was significant only when the saturation was original or enhanced [Original: $F(2, 1888) = 10.261$, $p < 0.0001$; +50 saturation: $F(2, 1888) = 4.200$, $p < 0.05$; -50 saturation: $F(2, 1888) = 0.150$, $p = 0.861$; -100 saturation: $F(2, 1888) = 2.876$, $p = 0.057$]. The tests of simple main effects revealed the same results of those in Experiment 1 with the exception of a significant main effect of lightness with conditions of original saturation.

Multiple comparisons were conducted by using Ryan's method [7]. With reference to the significant main effect of saturation, there were significant differences between +50 saturation and the original, between +50 and -50 saturations, between +50 and -100 saturations (ps < 0.0001), which were also significant in Experiment 1, between the original and -100 saturations, and between the original and -50 saturations (ps < 0.001), which were revealed significant in Experiment 2 for the first time. In relation to the significant main effect of lightness, there were significant differences between the original and +50 lightness ($p < 0.0001$), and between +50 and -50 lightness ($p < 0.01$). With regard to the significant interaction between saturation and lightness, when lightness was original or diminished (-50), differences between all pairs of saturation conditions with the exception of -50 and -100 saturations were significant (ps < 0.01). When lightness was enhanced (+50), differences between all pairs of saturation conditions except for the original and -50 saturations were significant (ps < 0.01). When the saturation was original or enhanced (+50), differences between the original and +50 lightness (ps < 0.05), and between +50 and -50 lightness (ps < 0.01) were significant.

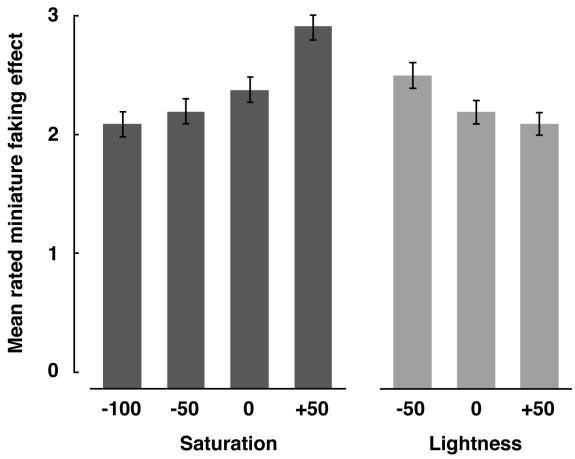

Figure 4. Results of Experiment 2. The mean rated miniature faking effects are shown as functions of saturation and lightness. Error bars denote SEM of the mean.

Based on the significant main effects of saturation and lightness, we plotted the rating values of miniature faking averaged over the 237 participants as functions of saturation and lightness (Fig. 4). Results revealed that the miniature faking effect changed systematically with alterations of saturation and lightness.

C. Discussion

In Experiment 2, all the significant results in Experiment 1 were replicated. However, some new findings were revealed. It was demonstrated that the miniature faking effect depended on the saturation.

Higher saturations induced a more enhanced miniature faking effect. The new finding was related to the relationship between lightness and the miniature faking effect. The results of Experiment 2 showed a significant decrease of the miniature faking effect in inverse proportion to the color lightness of the stimuli. The different roles of saturation and lightness are further explored in the general discussion.

IV. General discussion

In the present study, we conducted two experiments to examine the roles of lightness and saturation in inducing the perception of miniature faking. The functions of the two color attributes were both demonstrated by the experiments with a significant interaction with each other. The effect of saturation concurred with the findings of previous studies that garish colors yielded stronger miniature faking effects [4, 5, 6]. We are of the view that these results are linked with the finding that color saturation increases perceived object size [9] because the perception thereof leads to a reduction of observation distance, which is possible only when people view things in miniature or dioramas. However, further investigations are needed to examine whether the miniature faking effect occurs with the objects, or the entire landscape or environment in the photographs. In contrast to saturation, color lightness was shown to correlate inversely with the miniature faking effect. This new finding is supported by the fact that vignetting adjustment is an indispensable processing aspect when an ordinary photograph is recreated to become a miniature-like one. A previous study also found that darker photographs produced stronger miniature images when observed informally [4].

Although the influence of saturation and lightness on the miniature faking effect has been revealed in the present study, psychophysical investigations with more precise manipulations on color attributes as well as experiments conducted in a laboratory with controllable lighting environment are imperative in future investigations. Neurophysiological mechanisms of color perception and the miniature faking effect should also be explored.

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