Design Implications of Simultaneous Contrast Effects Under Different Viewing Conditions

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Abstract. This paper proposed that the viewing conditions for printed matters and projected images are quite different for three major reasons. Therefore, the brightness perception phenomenon and brightness perception theory generated from the printed matters should be revised and modified when applied to the projected images. The purposes of the present research were to examine the effects of brightness illusions while viewing the projected images, to understand the brightness perception process in projection environment, and thus to generate design implications for better usage of the projectors.

Keywords: Projector, Luminance, Brightness perception, Brightness illusion.

1 Introduction

One of the well-known brightness illusions is the simultaneous contrast effect. As shown in Fig. 1, the two central medium-gray squares are the same shade of gray, but look different because they are against different backgrounds. A square on a dark background looks brighter, and one on a light background looks darker. Previous researchers have proposed some explanations for this effect such as the lateral inhibition in the retina [4, 7], cognitive approaches [2, 6, 10], Gestalt approaches [3, 5, 8, 9], etc. Along with the remarkable progress and application of display projecting industry during recent years, more basic and applied research related to projecting efficiency and brightness perception are needed. However, most of the past studies regarding brightness perception are based on the research results from printed matters and cannot generalize to projected images.

The viewing conditions for printed matters and projected images are quite different for several reasons. First, people usually read printed matters at high level of illumination and the photopic vision (>3.4cd/m^2) is used in this situation. Cones on the retina are activated. On the other hand, dim illumination is applied to the usage of a projector and the mesopic vision (0.034cd/m^2~3.4cd/m^2) is used in this case. Both cones and rods are functioning when visual process takes place in dim lights.

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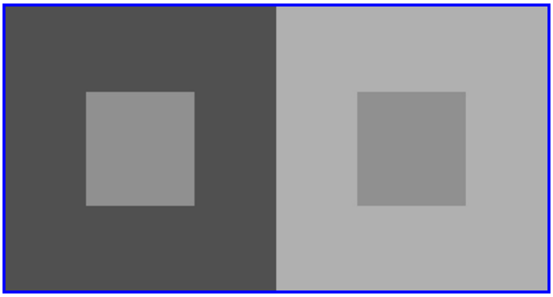

Fig. 1. The simultaneous contrast effect

Second, viewing distances and visual angles of the observed objects are dissimilar for these two viewing conditions. When a projector is used, the viewing distance is usually longer and the observed objects are larger. And, visual acuity is influenced by viewing distances and visual angles.

Third, printed matters are static real objects and projected images are dynamic virtual ones that are refreshed by light beams from a projector. For example, NTSC (National Television System Committee) runs on 525 lines per frame and its vertical frequency is 60Hz. These flashed pixels integrate in human brain to form visual experiences and perception.

Hence, the brightness perception phenomenon and brightness perception theory generated from the printed matters should be revised and modified when applied to the projected images. The purposes of the present research were to examine the effects of brightness illusions while viewing the projected images, to understand the brightness perception process in projection environment, and thus to generate design implications for better usage of the projectors.

2 Methods

2.1 Subjects

A laboratory method was adopted and thirty university students (10 females and 20 males, 20~24 years old) voluntarily participated in the present experiment. One color-blind test and one visual acuity test were used to screen the subjects to ensure their abilities in identifying color differences and having normal or corrected to normal visual acuity (above 0.9).

2.2 Experimental Design

The fully factorial within-subject design was applied in this study. Dependent measures were the perceived brightness levels and the measurement of photometric data collected using a luminance meter. Then, the derived illusions are operationally defined as the practical luminance values (measured by a luminance meter) minus the perceived ones (adjusted by subjects according to their perception). Hence, positive illusion values represent under estimation of the brightness; negative illusion values represent over estimation of the brightness; and no (or fewer) illusion error when this value is around zero.

Independent variables included two viewing conditions (looking at printed matters in bright illumination vs. looking at projected images in dim illumination), five luminance levels of the background areas (10, 30, 50, 70 and 90 cd/m^2), and five luminance levels of the center areas (20, 40, 60, 80 and 100 cd/m^2). Because the adjusted area was on a dark surrounding, people may perceive this area brighter than it really was according to the simultaneous contrast effect. In other words, in order to have the same brightness perception, people do not need to adjust luminance as bright as the compared square (center area). Therefore, under estimation of brightness may occur.

2.3 Procedures

Each subject experienced 50 experimental trials (2×5×5) in two stages; one for printed matters and the other for projected images. Within each stage, random sequences were used to counterbalance the possible fatigue or learning effects. When subjects completed one experimental trial, they might go to next randomly assigned trial until all trials were done.

At the stage of viewing projected images, the standard settings of projecting environment suggested by ANSI were applied [1]. Fig.2 is one sample tested screen programmed by Visual Basic before the experiment. Subjects used a scroll bar to adjust the luminance values of the experimental square (adjusted area in Fig. 2) until they perceive the experimental square having the same brightness level as the compared central square (center area in Fig. 2).

While looking at the printed matters, subjects examined several squares of different degrees of gray levels with a dark surrounding and chose one printout close to the brightness level of the compared center area.

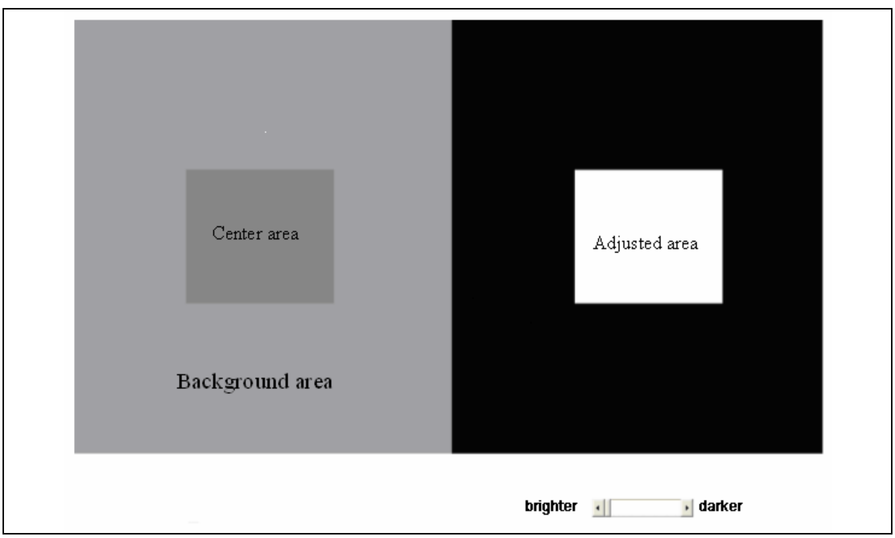

Fig. 2. One sample screen

3 Results and Discussions

Three-way ANOVAs with repeated measures were conducted to analyze the effects of two different viewing conditions and various luminance levels of center and background areas on brightness illusion. The ANOVA summary table and average values are provided in Table 1 and 2, respectively. Three-way interaction was

Table 1. The ANOVA summary table of the illusion values

Source of variance	Sum of square	d.f.	Mean Square	F_0	*P-value*
Viewing conditions(A)	18769.091	1	18769.091	225.356	0.000*
Error(A)	2415.309	29	83.287		
Background luminance(B)	4905.777	4	1226.444	23.969	0.000*
error(B)	5935.543	116	51.168		
Center luminance (C)	1741.231	4	435.308	10.253	0.000*
error(C)	4925.089	116	42.458		
AB	4081.116	4	1020.279	16.394	0.000*
Error	7219.084	116	62.233		
AC	3179.769	4	794.942	14.585	0.000*
Error	6322.631	116	54.505		
BC	2599.083	16	162.443	3.961	0.000*
Error	19027.597	464	41.008		
ABC	6629.824	16	414.364	9.864	0.000*
Error	19491.176	464	42.007		
Total	107242.3	1470			

* P< 0.05

Table 2. The summary table of the average illusion values

Projected images						Printed matters					
B \ A	10	30	50	70	90	B \ A	10	30	50	70	90
20	-4.40	-2.00	0.87	5.73	10.00	20	1.17	2.50	5.67	6.50	20.50
40	-5.47	-3.23	0.33	4.83	5.37	40	-1.00	-1.83	3.33	10.17	15.50
60	-7.53	-4.33	-0.13	2.67	4.13	60	-0.33	-2.83	1.67	7.33	5.50
80	-5.03	-3.27	-1.20	3.47	4.93	80	-3.00	-3.00	0.83	0.00	2.00
100	-4.93	-5.07	-0.60	2.97	5.80	100	2.17	-1.00	-0.17	2.00	5.50

A: luminance of background area (cd/m^2), B: luminance of center area (cd/m^2)

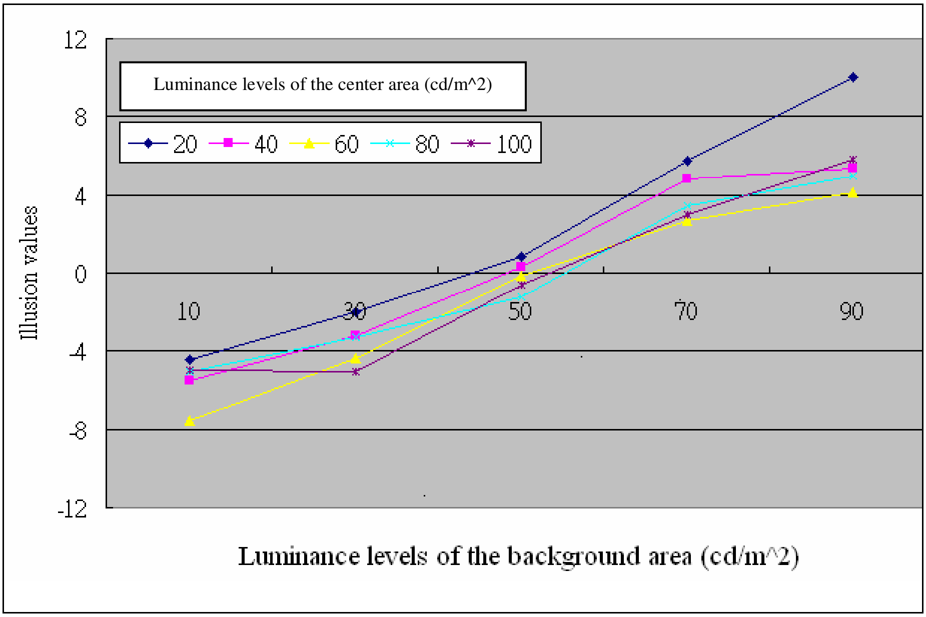

Fig. 3. The average illusion values while viewing projected images

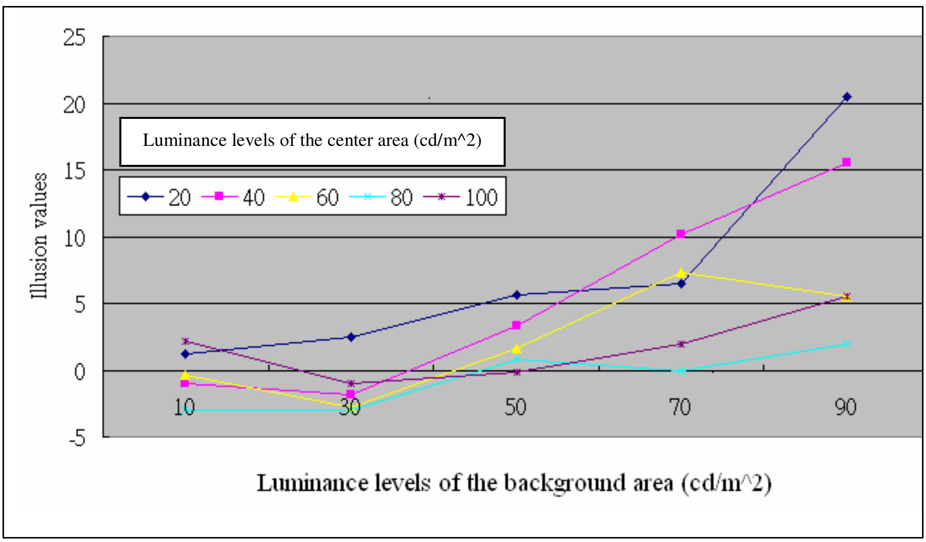

Fig. 4. The average illusion values while viewing printed matters

statistically significant and the other effects (including two-way interactions and main effects) were also significant. It means that simultaneous contrast effects were influenced by viewing conditions, background and center luminance.

The average illusion values under two viewing conditions were depicted on Fig. 3 and 4. On the other hand, the LSD post hoc analysis methods were used to examine the relationships between treatments. It indicated the illusion patterns along with various brightness contrasts while viewing projected images were significantly different from the ones while viewing printed matters. Few over estimation (few negative illusion values) and larger variance (ranges from -3 to 20.5) happened in printed matters condition. In other words, subjects experienced salient simultaneous contrast effects (perceiving brighter when surrounding is dark) in printed matters conditions; however, subjects depended on the combinations of center and background contrast producing brighter or darker perception in projected images condition. People may under or over estimate brightness while viewing projected images.

In addition, situations caused more brightness illusions were identified in this study. When projected images were seeing, there was nearly no brightness illusion at a background luminance of 50 cd/m^2; over estimation of brightness if background luminance lower than 50 cd/m^2; and under estimation of brightness if background luminance higher than 50 cd/m^2 (see Fig. 3). When printed matters were tested, the brighter the background area was, the larger the under estimation of brightness occurred especially if background luminance higher than 50 cd/m^2 (see Fig. 4). And, the illusions seemed to level off when background luminance is lower 50 cd/m^2 while viewing printed matters.

4 Conclusion

Since the display projecting industry is one of the most important industries during recent years, more basic and applied research related to projecting efficiency and brightness perception are needed. Especially, the findings of this research revealed the results of past studies on printed matters can not directly generalize to projected images. Therefore, more future research efforts regarding projector usage are highly encouraged.

It is also obvious that the physical luminance is not equal to the psychological brightness perception as the present and previous research indicated. In order to let projector users to "feel brighter", the luminance of background is suggested not to exceed 50 cd/m^2. Because the under estimation of brightness may happen when the luminance of background is above 50 cd/m^2.

On the other hand, even though basically the higher luminance of projected images the better the visual effects are. The images with luminance of 40-100 cd/m^2 have slight difference in brightness illusions. However, when luminance of a projected image as low as 20 cd/m^2 may deteriorate the projecting efficiency.

Finally, we'd like to emphasize that illusion is not a worse but a real phenomenon. Not only projectors manufacturers but also the designers of projected images and the projector users need to recognize this phenomenon and to make better usage of brightness illusion to create the visual experiences of perceiving brighter and clearer.

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