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# Brightness Contrast in Stereoscopic 3D Perception

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**Abstract**

This paper discusses the effect of brightness contrast on stereoscopic 3D (S3D) perception from a psychophysical viewpoint. It considers the way in which S3D perception is influenced by different decisions of brightness contrast, and identifies the thresholds of S3D perception in several brightness adjustments, which can provide guidance during colouring decisions for S3D imaging. In particular, different levels of brightness are tested on foreground and background objects to build brightness contrast in computer graphic scenes. Psychophysical trials are utilized to examine the thresholds of observers' depth perception. A polarised projection system is built for stereoscopic viewing and the image stimuli are rendered from stereoscopic virtual cameras by renowned 3D film making programme during experiments. The data indicates that it was able to provide a significant effect over the brightness adjustments in controlling the perceived depth in stereoscopic perception, and darker object in foreground with brighter object in background result stronger stereoscopic 3D perception.

**Introduction**

Two objects of identical size but different brightness lying in the same plane appear to be at different distances. When the background is darker than both objects, the brighter object appears nearer [9]; when the background is brighter than both objects, the darker object appears nearer [5]. The findings then were concluded the object having the greater

brightness contrast with the background is perceived to be nearer [3].

### Brightness in Depth Perception

The brightness phenomena are from the association of past experience with aerial perspective. Brighter objects stimulate the retina more intensely and therefore give more vivid impressions than darker ones [10]. From everyday experience, moreover, we know that a nearby object is seen more clearly than the same object further away. Thus, the clarity of visual impressions due to brightness can be interpreted as proximity. Some studies have shown that of two objects of the same physical size the brighter is perceived to be larger than the darker [8], irrespective of the brightness of the background [7].

Others explained the adjustment of the pupil as a cause of the effect of brightness on perceived distance from the observer [2,10]. The pupil size changes not only with illumination but also with convergence and accommodation—decreasing when a nearer object is viewed [1]. Consequently, when the pupil constricts on viewing a brighter object, this change can be interpreted as the object being nearer. Some explanations assume that differences in brightness yield binocular disparities [9].

While these literatures clearly indicate that brightness interact with depth perception, their significance with regard to stereoscopic depth perception has not been further investigated. From design aspect, either brighter object in foreground with darker object in background or darker object in foreground with brighter object in background can construct brightness contrast and contribute to depth perception. However, which approach is more efficient regard to S3D imaging? Is brightness a critical consideration in S3D perception and applicable for current stereoscopic imaging productions? This paper examines the thresholds of brightness contrast for stereoscopic depth perception based on human factor experiments.

## Methods

### Psychophysical Trials

To provide the examinations of different brightness in stereoscopic perception, this paper employed psychophysical experiment for the measurement of threshold values. The method of constant stimuli was chosen as the method is considered to provide robust and precise estimations of threshold and other parameters [4]. Psychometric functions were constructed based on seven stimulus levels and 50 trials per level, using a 2AFC procedure. 2AFC minimises the likelihood of criterion shifts and also reduces the possible effects of interval-selection bias [6].

### Apparatus

A polarized projection system was built for stimuli observations. The current RealD 3D cinema uses circularly polarized light to produce stereoscopic image projection [11]. The stimulus images were projected by two same model DLP projectors onto a silver screen, observers were required to wear a polarized glass to fuse the left and right images at a fixed viewing distance. Figure 1 illustrates the polarized stereoscopic 3D projection.

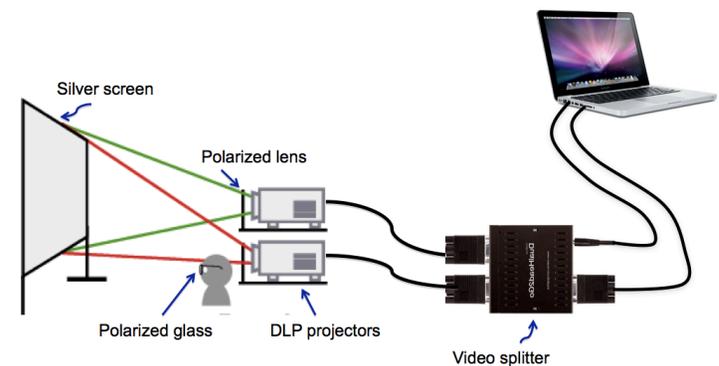
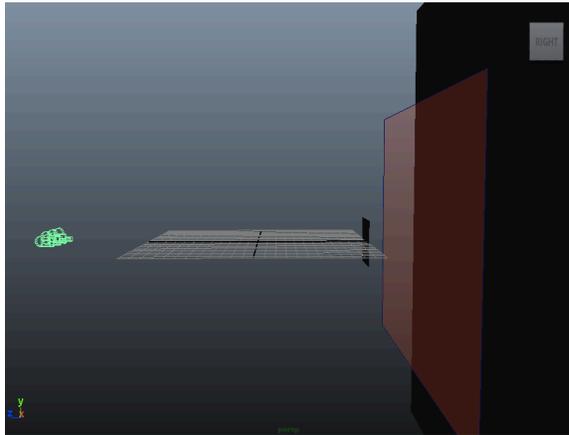


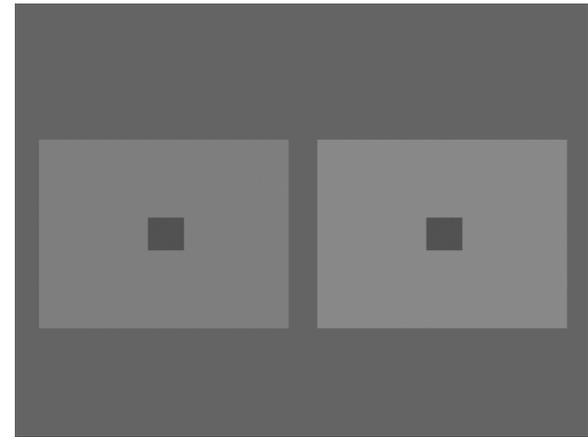
Figure 1. Polarized Stereoscopic 3D Projection

### *Stimuli*

The image stimuli were rendered in Autodesk Maya 2012 and composed simply by a foreground small square located in the centre of a background large square, which avoid any other possible depth cue. The two objects in the scene were located within stereoscopic comfort viewing zone that suggested by the visualization tool in Maya. See Figure 2 and 3 for the stimuli design. In order to provide equal comparisons, brightness contrasts between foreground and background were controlled in certain ratios. Seven levels of different contrast ratios from 2.0:1 to 2.6:1 between foreground and background squares with 0.1:1 step size difference were associated to brightness parameter in Autodesk Maya range from 26% to 78%.



**Figure 2.** Stimuli design in Autodesk Maya. The green object on the left is the virtual stereo camera. The red panel on the right is a visualized aid in Maya that represents display screen to assist designers measuring the distance between objects and the screen.



**Figure 3.** Stimulus image. Subjects are required to choose which side of the images is perceived more stereoscopic depth.

### *Procedure*

There are two sections in the experiment. The first one is to examine brighter square in foreground with darker square in background; the second section is for darker square in foreground with brighter square in background. Seven subjects who met the minimum criteria of 20/30 vision, stereo-acuity at 40 sec-arc and passed the colour vision test participated the experiment. Every observation includes a standard stimulus with the contrast ratio 2.3:1 side by side with a comparative stimulus presented randomly from contrast ratio 2.0:1 to 2.6:1. Observers are asked to record their decision by choosing the image they perceive more stereoscopic depth between the foreground object and the background object.

### **Results**

Psychometric function which shows the relationship between the percentage of times that a stimulus is perceived and the corresponding stimulus intensity. Point of subjective equality (PSE) is then obtained at 50% of psychometric function. The mean score and

standard deviation for two sections are shown in Table 1.

Subject	Section 1 PSE (Contrast Ratio)	Section 2 PSE (Contrast Ratio)
LD	2.25	2.28
AM	2.33	2.29
RE	2.20	2.30
EN	2.35	2.28
MJ	2.6	2.29
GC	2.32	2.31
JK	2.20	2.28
Mean	2.32	2.29
St. Dev.	0.14	0.01

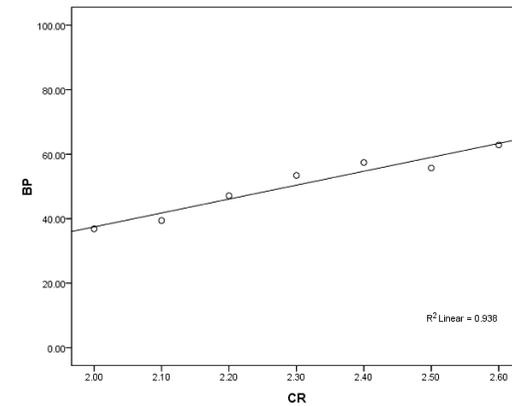
**Table 1.** Mean and std. deviation of PSE

In Section 1, three subjects out of seven have lower contrast ratio than standard ratio 2.30:1 and the mean is 2.32:1 which is very close to standard ratio. In Section 2, six subjects have lower contrast ratio and the mean is 2.29 which is almost equal to the standard ratio. The results from Paired T-Test comparisons between PSE in two trials revealed that there is no statistically significant difference between two sections.  $p > 0.05$ , fail to reject  $H_0$ . See Table 2 for the hypotheses and T-test results.

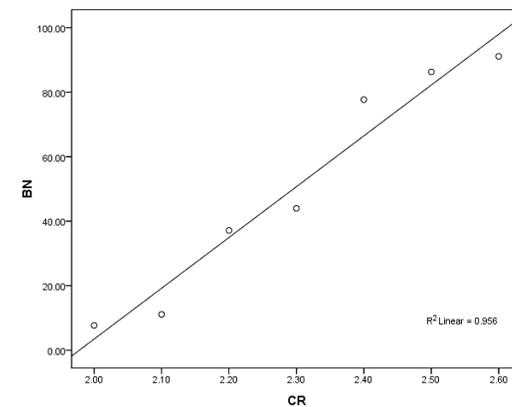
Hypothesis $H_0$	Two-tailed P value	Conclusion
$H_0: \mu_{sec.1} = \mu_{sec.2}$ v.s.	.57	Fail to reject $H_0$
$H_1: \mu_{sec.1} > \mu_{sec.2}$		

**Table 2.** T-test result concerning sec.1 and sec.2 trials

The coefficients in linear regressions indicate slopes in two trials are significantly different from 0, which means there is a significant relationship between hue and S3D perception as  $\beta \neq 0$  at  $p < 0.05$ . See Figure 4, Figure 5 and Table 3.



**Figure 4.** Linear Regression from Section 1.



**Figure 5.** Linear Regression from Section 2.

Hypotheses	P value	Conclusion
$H_0: \beta_{\text{sec.1}} = 0$ vs. $H_1: \beta_{\text{sec.1}} \neq 0$	.000	Reject $H_0$
$H_0: \beta_{\text{sec.2}} = 0$ vs. $H_1: \beta_{\text{sec.2}} \neq 0$	.000	Reject $H_0$

**Table 3.** T-test results of slopes

A univariate analysis of variance was then performed on the comparison concerning the slopes. The result showed there is significant difference between the variances in Section 1 trial and Section 2 trial as  $p < 0.05$ . See Table 4.

Source	Sum of Squares	df	Mean Square	F	Sig.
Sec.1 * Sec.2	1832.116	1	1832.116	51.258	.000

**Table 4.** Univariate analysis of variances

### Conclusion

In this study, thresholds for alternative forced choice of brightness with stimulus levels controlled by contrast ratio were measured. Statistics confirmed that it was able to provide a significant effect over the brightness adjustments in controlling the perceived depth in stereoscopic perception. We also confirm that either brighter object in foreground or darker object in foreground could effect on stereoscopic perception. However, there were indications in our results suggesting that with fixed contrast ratio there is significant difference between the two approaches. Brighter colour in foreground has significant weaker contribution to S3D perception than darker colour in foreground.

It is proposed that the considering brightness contrast is beneficial on stereoscopic perception, but viewers can perceive stronger stereoscopic intensity under brightness contrast associated with darker foreground with brighter background.

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