VOLUME 13 NO.1
JUNE 2016
ISSN 1675-7017

SOCIAL and MANAGEMENT RESEARCH JOURNAL

Institute of Research Management & Innovation (IRMI)

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Vol. 13 No. 1 June 2016 ISSN 1675-7017

Comparison of Visibility Threshold on Different Chromatic Contrast Objects

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ABSTRACT

The aim of this study was to compare the visibility threshold of eight plates with different chromatic contrast. The staircase psychophysics method based on the resolution of gaps in Landolt C was used to determine the average visibility threshold. Thirty young adults with best-corrected visual acuity of 6/6, normal colour perception and no history of ocular diseases were recruited. The results showed a combination of white on blue background plate gave a highest visibility level (mean=44.48±6.37m), while red on a blue background was the least visible combination (mean=33.30±4.68m). In conclusion, the chromatic contrast of an object can affect the visibility threshold.

Keywords: *chromatic contrast, visibility threshold*

INTRODUCTION

Visibility is the strength of an object's features such as its chroma, luminance, form, size, etc. (Wertheim, 2010) (Porathe, 2008). The chroma or colour contrast plays an important role in detection and recognition of an object. Visibility is one of the important elements in objects detection (Palomares & Egeth, 2010) (Porathe & Strand, 2011). A proper chromatic contrast helps in better visual performance especially in detection and recognition of an object. Although the features of an object (e.g. colour, contrast, brightness and size) affect the visibility, different background with same object can yield different level of visibility (Porathe & Strand, 2011).

In Wertheim's study, the possibility of chroma or colour recognition criterion was measured using the Wertheim's psychophysics methodology (Wertheim, 2010) (Porathe, 2008). It was concluded that colour recognition of an object was inferior to the detection criteria. This suggested that colour perception does leave an impact on object's visibility.

The information of surrounding environment should be utilized effectively and efficiently. A proper chromatic contrast increases visual performance of any task (Crundall & Underwood, 2001). This is because higher visibility objects aid in visual detection when there is limited time to response. Thus, it is hypothesized that higher chromatic contrast would provide higher visibility and hence enhance the visual detection performance.

While the literature has frequently showed most of the study was carried out on a computer image, the impact of chromatic contrast on real image however has not been considered. This paper elaborate further on the investigation of chromatic contrast on real object uses eight colour combinations. The output might be utilized for future designs and technologies on related applications.

MATERIAL AND METHODS

Overview

This study was intended to answer the question: does the difference in chromatic contrast affect the visibility of an object? A uniform condition of experiment was designed (psychophysical experiment) to test on the visibility threshold of gap detection in eight-colour combinations.

Experimental design

This study was a cross sectional study design and used a non-probability convenience sampling method. Independent variable was chromatic contrast of the object (8 plates) and was investigated with dependent variables being visibility level (distance in meter). The dependent variables were analysed using repeated measures ANOVA. Repeated measures ANOVA was chosen because same participants were used throughout the experiment for each objects used and the measurement of the dependent variable is repeated.

Stimuli

The target stimuli were Landolt C plates constructed on eight different combinations of chroma. Landolt C was chosen because it was proven to be better than any other optotype such as Tumbling E, Snellen, etc. (Bondarko & Danilova, 1997). Figure 1 showed the construction of Landolt C on a grid framework. The size of the Landolt C was downscaled to 4 times smaller to accommodate with the space available in the laboratory setting. Each of the Landolt C plate was 15 cm x 15 cm while the size of Landolt C was 5 cm x 5 cm. Each limb of Landolt C was standardized as 1 min of arc. Thus, 5 cm x 5 cm represents 5 min of arc.

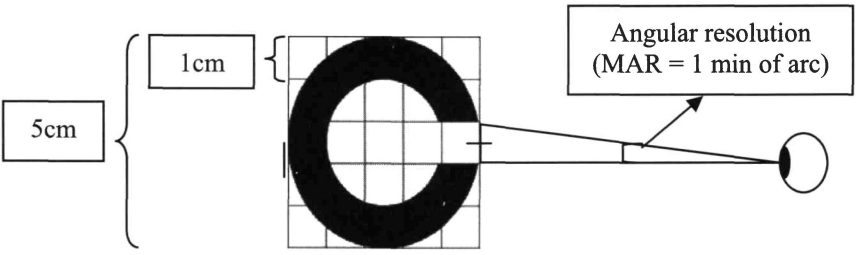

Figure 1: Constructed Landolt C on a Grid Framework

The material used to construct the plate was a retro reflective plate as has been established and approved by the Jabatan Kerja Raya (JKR) (JKR, 1985). The chromatic combinations used were selected based on the road sign designs that were currently being used in Malaysia. The eight combinations were as follow:

1. White on blue background
2. White on green background
3. Black on yellow background
4. Black on white background
5. Black on orange background
6. Red on white background
7. Red on blue background
8. Yellow on green background

Experimental room

The experimental took place in a normal ambient room illumination; 642 lux to 647 lux (SD: ±5 lux). The participants were standing at an initial distance of 60 meter from the target. The target was mounted on a pole at the left side of the participant.

Participants

Thirty healthy participants aged between 19 to 25 years old were screened for their visual acuity and colour vision. The inclusion criteria were corrected visual acuity of 6/6, pass Ishihara colour vision test (24

plates) and have no history of ocular disease. The study was approved by the ethics committee of Faculty of Health Sciences, UiTM Puncak Alam.

Procedure

Landolt C plate was randomly positioned in any of four directions as indicated in the Figure 2 (right, left, upward and downward) and the participants were instructed to indicate where the gap was located. From the initial working distance of 60 meter, the participants were asked to move forward by 1-meter step towards the plate by ascending method (from non-seeing to seeing) until they were able to indicate the direction of the gaps. Then, they were asked to move backward (descending method) until they were unable to detect the gap anymore. The combination of these methods called staircase method. The results of visibility level then were averaged according to these distances to obtain the visibility threshold.

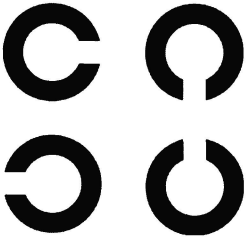

Figure 2: The four directions of Landolt C

RESULTS

Target visibility; the threshold determination

The psychophysics method involved in the determination of a threshold (the minimum visibility distance of the plate being detected). Figure 3 showed the visibility threshold determination using psychophysics staircase method (Schwartz, 2010).

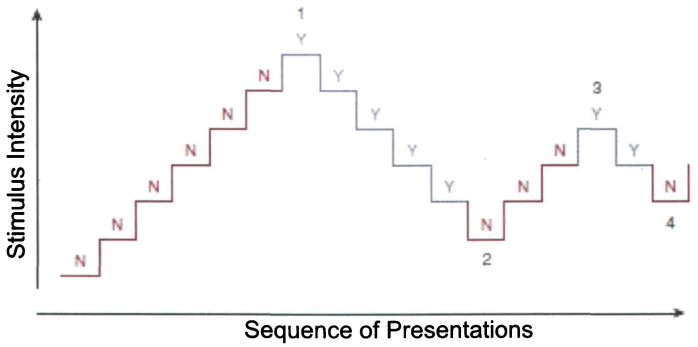

Figure 3: Staircase method for threshold determination. The visibility distance was increased from non-seeing (N); ascending method to seeing (Y); descending method. A reversal occurred at point 1 and decreased until point 2. Threshold was taken at reversal 2. (Adopted from *Visual Perception, A Clinical Orientation, 4th Edition, 2010*)

Target detection; the effect of chromatic contrast

One-way repeated measures ANOVA was conducted to determine whether there were statistically significant differences in visibility level for different colour combination. There were no outliers and the data was normally distributed, as assessed by boxplot and Shapiro-Wilk test ($p > 0.05$), respectively. The assumption of sphericity was violated, as assessed by Mauchly's test of sphericity, $\chi^2(2) = 51.64, p < 0.01$. Therefore, a Greenhouse-Geisser correction was applied ($\varepsilon = 0.65$). The colour combination statistically significant changes in visibility level [F (4.45, 128.93) = 18.81, $p < 0.01$].

Post hoc analysis with a Bonferroni adjustment revealed that the mean visibility level was statistically significantly different between white on blue background and three other colour combinations; which were black on orange background, red on white background and red on blue background; $p<0.001$, $p<0.05$ and $p<0.001$ respectively. The highest visibility was reported for white on blue background (44.48±1.16).

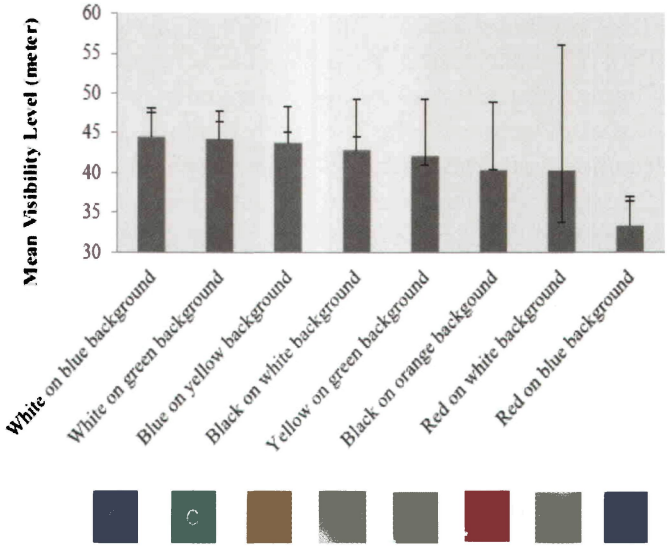

Figure 4: Chromatic Contrast as a Function of Visibility

DISCUSSION

The aim of this study was to investigate the effect of chromatic contrast of an object on visibility. The discussion here will consider the objects detection and the visibility. The result indicates that chromatic contrast have a major effect on object visibility. The result from this laboratory experiment strengthened the findings of previous field study that the chromatic contrast affected the visibility of an object by improving as high as 50% of an object detection (Terry & Gibbons, 2011).

The highest visibility among the 8 plates was the white on blue background combinations. White on blue background was easier to see and was detected at greater distance than others. The white on blue combination provided good visibility level and it showed that this chroma combination have sufficient level of luminance contrast between letter and background. On the other hand, the chroma combination of red on blue background was more difficult to see and was only detected at closer distance.

In any real situation, chromatic component may change with several factors such as varying distance, visual angles, and weather (Aoyagi & Asakura, 1996). The highest visibility is proper to be use on route navigation. A potential implication of this study can be applied in the understanding of factors on object detection among road user. It allows for certain criteria of object detection that can be made into standard requirements for objects such as traffic signs, advertisements, etc. It indicates that the findings from this study is relevant with current utilization and can be made into standard requirements for improving current road sign design. This fundamental concept is very important in implementation of road sign design and application. Moreover, a visible and conspicuous road signs are very important as it improved safety and awareness toward road users.

LIMITATIONS OF STUDY

Our findings were limited to the available space used in the laboratory setting. Further experiment in field study is required to compare discrepancies between laboratory and fieldwork. In addition to that, present study performed in a controlled environment, where the probability of plate being noticed is high. The four directions of the Landolt C used in this study can be improved further using eight directions which include the oblique orientation of the Landolt C (Bondarko & Danilova, 1997).

SUMMARY AND CONCLUSION

A proper chromatic contrast of an object gives better visibility. It enhances the visual performance by increases the ability of the objects detection. As shown in our study, the chromatic contrast of white on blue background can be detected at larger distance compare to others. Therefore, it is suitable to be apply on long-range road such as at highway and suitable to the road users travelling at high speed.

In conclusion, the chromatic contrast of an object could affect the visibility threshold. It improves the objects detection and enhances the visual performance. Given this consideration, care must be taken when applying in road sign design particularly when involving the chromatic combination. This is because some colour combination may cause chromatic aberration, in which it leads to an additional visual problem in the eye (Ojanpää & Näsänen, 2003). Further effort is required to determine the contributory factors of these effects. The age of the observer and the lighting system are good to be considered in future study.

ACKNOWLEDGMENT

This research was supported by Fundamental Research Grant Scheme (FRGS) 600-RMI/FRGS 5/3 (118/2014).

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