

The effect of target with different wavelength on accommodation error among Myopes

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Abstract: Myopes demonstrated larger accommodation error for near visual targets than emmetropes. This study was to investigate the comparison of accommodation error among myopes with different color component of visual targets. Four different colored rectilinear crosses; black, blue, green and red, on white background were used as visual target at the distance of 40 cm (+2.50 Diopter of accommodation demand). Accommodation error was calculated from the difference of the demand and response, measured using dynamic cross-cylinder procedure. One-way ANOVA showed a significant difference in accommodation error when subjects viewing different coloured targets ($F(3, 92) = 16.72, p < 0.001$), while Tukey HSD test indicated the accommodation error with red color was significantly lower than the black. The finding implied that longer wavelength color affected accommodation greater than shorter wavelength.

Keywords: Accommodation error, dynamic cross-cylinder, visual targets, color, myopes.

Introduction

The use of conventional black and white colors in printed materials was common especially in hardcopy books and papers. However, with the advancement in printing and display technology, everyone was exposed to various color-related near works and no longer being limited to the black and white prints. Nowadays, colored targets were used in books, magazines, electronic displays and devices such as iPad and mobile phone. As such, color was widely used in near work material as reading text, even in electronic books and also as graphical material. Therefore, visual status with these materials became an issue as both hardcopy and electronic displays were associated with eye discomfort, though it was significantly higher with the displays [1].

There were various visual symptoms associated with these electronic displays such as eyestrain, dry eye, eye discomfort and even blurriness especially after long hours of viewing. Eyestrain and sore eye occurred frequently with prolonged exposure to the electronic display of more than 7 hours daily, and were followed by the symptoms of blurriness, itching and red eyes [2]. As electronic displays and devices used illuminated screens, factors including flickers rate, light exposure and pixel density might contribute to these visual symptoms. Furthermore, the use of colors or chromatic components in the electronic devices could affect the vision especially at near. Chromatic components and luminance of stimulus presented to subjects during near work highly influenced the accommodation response, thus color was suggested as a factor to accommodation efficacy [3].

During near work, the ocular system had to respond to the near visual target to produce sharp retinal image by accommodating. There were several factors influenced the accommodation response including optical defocus, chromatic aberration, perceived distance, proximity, contrast, voluntary effort and cognitive demand [4,5]. Broad-band targets with normal chromatic aberration were better stimuli for accommodation than monochromatic target. However, the accommodation response for various chromatic targets varied among individuals [6].

Accommodation error occurred when the exerted accommodation response differed from the demand of accommodation. This was due to the difference in the position between visual target and retinal conjugate point [7]. As accommodation stimulus was reciprocal to the distance, a 40 cm near visual target generated accommodation stimulus of +2.50 D. An accommodation error of +0.25 D indicated that the conjugate point was behind the retina and this condition was known as lag of accommodation. The blurred retinal image produced by the lag of accommodation was associated to the axial elongation of the eye in myopia. Myopic eye showed an increased lag of accommodation or larger accommodation error for near targets than the emmetropic eye [8,9]. Thus, myopic individuals were more likely to under-accommodate when doing near work compared to emmetropes. However, when colored background was used as visual target, there was a reduction in the lag of accommodation [10].

This suggested that with the use of color, the accommodation could be affected especially in myopia. Therefore, the stimulus color component could provide marked stimulus for accommodation response. However, the type of wavelength based color component target that could affect the accommodation among myopes via printed materials had yet to be identified. This study was conducted to investigate the effect of long and short wavelength based color components together with achromatic target on accommodation error among myopes.

Materials and Methods

Rectilinear cross targets on white background were used as a target for this study as illustrated in Figure 1. This cross target was used in conjunction with cross-cylinder lens to present two different foci on the retina, using the concept of circle of least confusion [11]. The accommodation error was measured using neutralizing spherical lens that made the two meridional lines to be equally clear to place the circle of least confusion properly on the retina. The technique of measuring accommodation error was described elsewhere [12]. The rectilinear targets were similar in size, shape and design, with the difference only in the color of the targets.

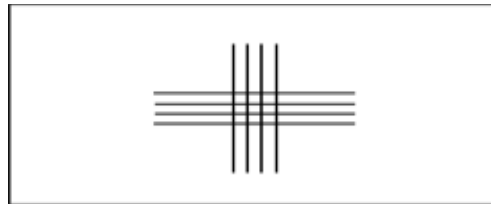


Figure 1: Rectilinear Cross Target

As rectilinear cross target was a hardcopy target rather than electronic display, the rectilinear target was printed according to Red-Green-Blue (RGB) values. RGB was a color reproduction system that was used in various colors imaging technology including in color printing [13]. This system was based on the three primary colors that were defined under white point standard illuminant. Color printing usually combined cyan, magenta, yellow and black inks to produce appropriate color mixture. The prominent mixtures of the printing were red, green and blue colors, though the color appearance of the hardcopy prints might not completely similar to the electronic display.

Based on the RGB values, four types of target were introduced in this study. Apple DigitalColor Meter was used to measure the approximate generic RGB values of all the rectilinear cross targets which were scanned to the computer first. The approximate generic RGB values were 71-79-75 which appeared as black, 225-99-86 which appeared as red, 110-205-85 which appeared as green and 80-92-194 which appeared as blue. The appearance of red, green and blue colors was chosen as the colored targets as they were the primary colors, based on Helmholtz-Maxwell's trichromatic vision model. Thus, red represented long-spectrum, green represented medium-spectrum, blue represented short-spectrum while black represented achromatic component.

This study involved twenty-four young adults with the age ranged between 19 and 25 years old as subjects. All of the subjects were myopic with spherical component was worse than - 1.00 D and the cylindrical component was up to - 1.00 D [8]. With the best vision correction, the distance visual acuity was 6/6 based on Snellen scale and near visual acuity was N5 at 40 cm based on near reading chart. There was no remarkable binocular vision problem and none of the subject had been exposed to the colored rectilinear cross target before the procedure. Written consent was taken prior to the participation in this study. Ethical approval was obtained from Universiti Teknologi MARA to ensure the study adhered to the Declaration of Helsinki.

Procedure

Phoropter was used to measure accommodation response under full correction. Accommodation demand of +2.50 D was induced by placing a standard rectilinear cross target of black print on white background at a viewing distance of 40 cm. Measurement of accommodation response to the stimulus was conducted using dynamic cross-cylinder procedure. Cross-cylinder of ± 0.50 D with minus axis set at vertical meridian was introduced binocularly before the subject's eye upon viewing the rectilinear target. When the horizontal lines were initially reported clearer than vertical lines, a + 0.25 D of spherical lens was added binocularly at a time until the vertical lines became clearer. However, when the vertical lines were initially reported clearer than horizontal lines, a - 0.25 D of spherical lens was added binocularly at a time until the horizontal lines became clearer. The added spherical lens was then reduced binocularly until the clarity of both vertical and horizontal lines were equal. If both lines were not equally clear, the measurement was taken based on the lens that made the previously blurred lines to be clearer. The accommodation error was taken from the difference between the accommodation response and accommodation stimulus demand which was obtained from the value of lens power required to make the two sets of lines appeared equally clear [14].

Results

All of the data were normally distributed based on Shapiro-Wilk test of normality values ($p > 0.05$). The subjects varied according to the age with the mean were 22.04 years old (± 1.52) with 25% subjects were males and 75% subjects were females. The mean spherical component for both eyes was - 2.54 DS (± 1.03) and the mean astigmatism cylindrical component was - 0.29 DC (± 0.19). The mean of accommodation error of black, green, blue and red targets was + 0.41 D (± 0.20), + 0.39 D (± 0.24), + 0.31 D (± 0.21) and - 0.02 D (± 0.29) respectively as demonstrated in Figure 2. One-Way ANOVA statistical analysis was used to compare accommodation error amongst the four-colored targets. There was a significant difference in accommodation error when subjects viewing different coloured targets ($F(3, 92) = 16.72, p < 0.001$). Post hoc comparisons

using the Tukey HSD test showed that the mean accommodation error for the red target was significantly different than the black target ($p < 0.001$). However, the mean accommodation error for the green target and blue target did not significantly differ between themselves and from the black and red targets respectively ($p > 0.05$).

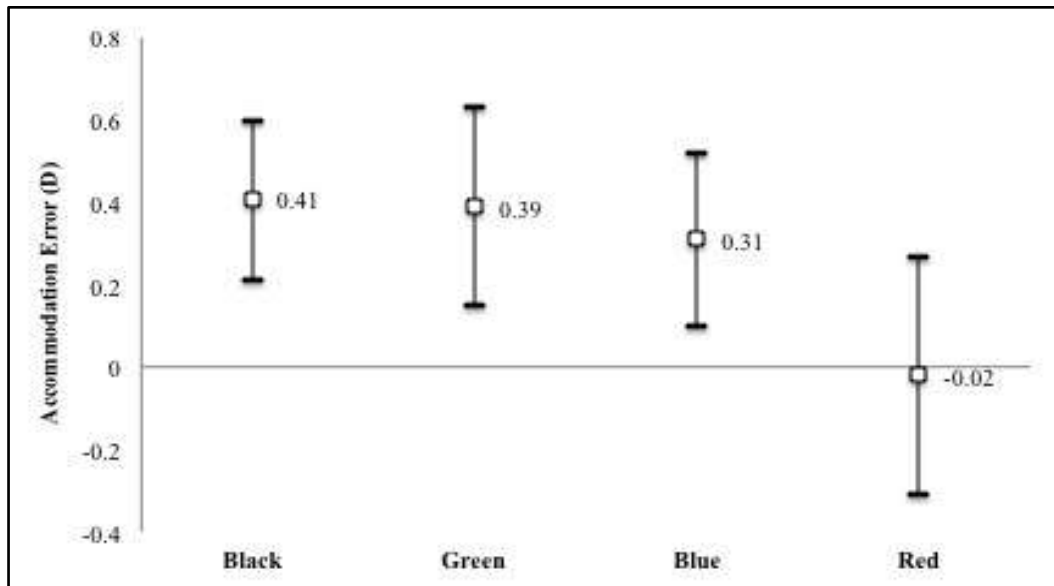


Figure 2: Accommodation error was plotted against target with different wavelength (black, green, blue and red)

Conclusion

Our findings conformed that accommodation error was significantly lower in red target than black target. The red target showed the lowest accommodation error, while on the other hand, black target produced the highest accommodation error among all visual targets used in this study. This current result was consistent with previous study that found the color component of visual stimulus could induce different accommodation responses [6,15]. However, the significance was not found in blue and green targets.

As the target colors were blue, green and red, on white background, the accommodation response changed based on the chromatic contrast of the target. Greater accommodation response was reported with monochromatic (gray) condition compared to colored background [10]. Our findings suggested that the accommodative effort was greater when viewing red letters compared to blue letters as previously discovered [5]. Blue condition showed shorter response latency as opposed to the other colors [3]. This implied that the accommodation effort to blue (shorter wavelength) was lesser as it was rapidly directed to the retina. As the red target was consisted of long-wave spectral properties, the eye increased the accommodation effort to compensate for the dioptric distance of the target. This could be described by cone weighting factors. The increased sensitivity to one or other cone type was expected to increase chromatic response [16]. This eventually decreased the accommodation error in order to improve the accommodation response of near target. Nevertheless, as the color properties in printed material might be different from electronic visual display, this chromatic response could be affected more prominently when using the display.

Another possible explanation to the decrease in accommodation error with red target was the attentiveness to the color targets. Emotional responses to color varied with the chromatic component used throughout the different hue categories. Red was illustrated as exciting, which gave higher rate of stimulation compared to other colors [17]. Since the subject perceived red target was more attentive, the effort to focus to the target was greater than the other colored target. The less attentiveness to the green and blue target could be due to the feeling of relaxation, calmness and comfort that were associated with both colors. This study was a preliminary study to ascertain that color did affect accommodative error. However more thorough study was needed to look into the accommodation error with various electronic displays and also with different hues and chromatic contrast. However, as the current study was done binocularly, the binocular viewing condition could be helpful in producing more accurate accommodation response than monocular viewing [18]. Nevertheless, the present study concluded that the longer wavelength (red) color could reduce the accommodation error and generated more accurate accommodation response than the shorter wavelength color.

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