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Laser Eye Protection and the Effect of Two Types of Light-Emitting Diodes (LEDs) on Color Perception

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16. Abstract

The purpose of this study was to explore the effect of laser eye protection (LEP) devices on color perception of aviation signal lighting. Aviation signal lighting utilizes two types of light emitting diodes (LEDs): 1) Single-die (SD) LEDs that produce only one color and 2) Red-Green-Blue (RGB) LEDs that create colors by mixing the RGB primaries. LEP glasses block colors that are commonly used in commercially available lasers. Since many of these lasers emit in the same band as some LEDs, LEP glasses may block some emissions from LEDs as well and could interfere with accurate perception of aviation signal lighting. Twenty-three participants with normal color vision viewed SD and RGB LEDs with and without LEP glasses. Accuracy of color identification and reaction time were measured. Results indicate that the effect of LEP glasses on color perception varies based on LED color and LED type. Implications for aviators are discussed.

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Introduction

The Federal Aviation Administration (FAA) is planning to convert from incandescent lights to light-emitting diodes (LEDs) in aviation signal lighting applications to save energy. The purpose of this study was to explore the effect of laser eye protection (LEP) devices on color perception of signal lighting.

There are two major types of LEDs; single-die that produce only one color and Red-Green-Blue (RGB) LEDs that create color in a manner similar to a monitor or LED TV. RGB LEDs create light using mixtures of red, green, and blue light from three primary color emitters. The three primary colors are turned on at varying intensities to produce millions of precisely defined colors (Viliūnas, Vaitkevičiu, Stanikūnas, Švegžda, & Bliznikas, 2011). The ability to produce such a vast number of colors is one of their key benefits.

Aviation signal lighting devices can use either single-die (single-color) or RGB LEDs. At the current time, RGB LEDs are not as common in most applications given their greater cost and size when compared to a single-die LED. There are currently no restrictions against using RGB LEDs in aviation applications but their cost is a limiting factor. LEP glasses work using notch filters that block the specific emissions from commercially available lasers. Many of these lasers emit in the same band as the green primaries in RGB LEDs. This means that aviators using LEP glasses will generally experience erroneous color perceptions from some RGB LEDs. The effect is that of removing one or more of the LED's primary colors from the perceptual environment, rendering the LED dichromatic or potentially monochromatic.

The way that color is created differently by single-die and RGB LEDs is of major concern. For instance, although the light from an RGB and single-die LED may appear to be the same yellow hue, they are, in fact, different in composition. The single-die LED is only emitting yellow light, whereas the RGB LED is creating yellow by mixing green, red, and, potentially, a small amount of blue light. Thus, if one of the primaries (red, green, or blue) is blocked by the filters in LEP glasses, the light will not appear to be yellow to that observer. The most common result is that the yellow light would appear to be red.

RGB LEDs create white light by mixing all three primaries. It is possible to have a green or blue light that is also created using some amount of light from the other primaries. Thus, it is generally the case that LEP glasses with a green filter will cause white and amber/yellow lights to appear red and can potentially interfere with accurate perception of some greens and blues. Therefore, the purpose of this study was to evaluate the perceptual differences that occur when viewing RGB LEDs both with and without LEP glasses.

Method

Scores on the Colour Assessment and Diagnosis (CAD) test determined the color vision diagnoses for participants. Only participants with normal color vision (NCV) (n = 23) were included in the study. There may be some challenges when LEP protection is used by CVDs to view RGB LEDs. However, that was beyond the scope of the current effort and remains an open empirical question.

An experimental device developed at the Civil Aerospace Medical Institute (CAMI) aided in exploring the challenges of using RGBs for aviation signal lighting. Participants were seated in a darkened room and viewed the LEDs at a distance of 15’. Participants completed two tasks. Both tasks were presented in conditions with and without LEP glasses.

The first was a color identification task in which participants viewed single-die (SD) LEDs and RGB LEDs one at a time and pressed a button corresponding to the perceived color (yellow, blue, green, red, white). The second task was a comparison task between a single-die LED and an RGB LED. Two lights were presented simultaneously and the subject was asked if they appeared to be the same or different colors (Figure 1). Some stimuli pairs had chromaticities that matched or were at least the same basic color (e.g. two shades of red), and other stimuli pairs that were not matches were added to the test as distractors. This approach was critical for determining where the LEP glasses may be introducing color confusion lines.

The dependent variables were accuracy and reaction time (RT) on both tasks.

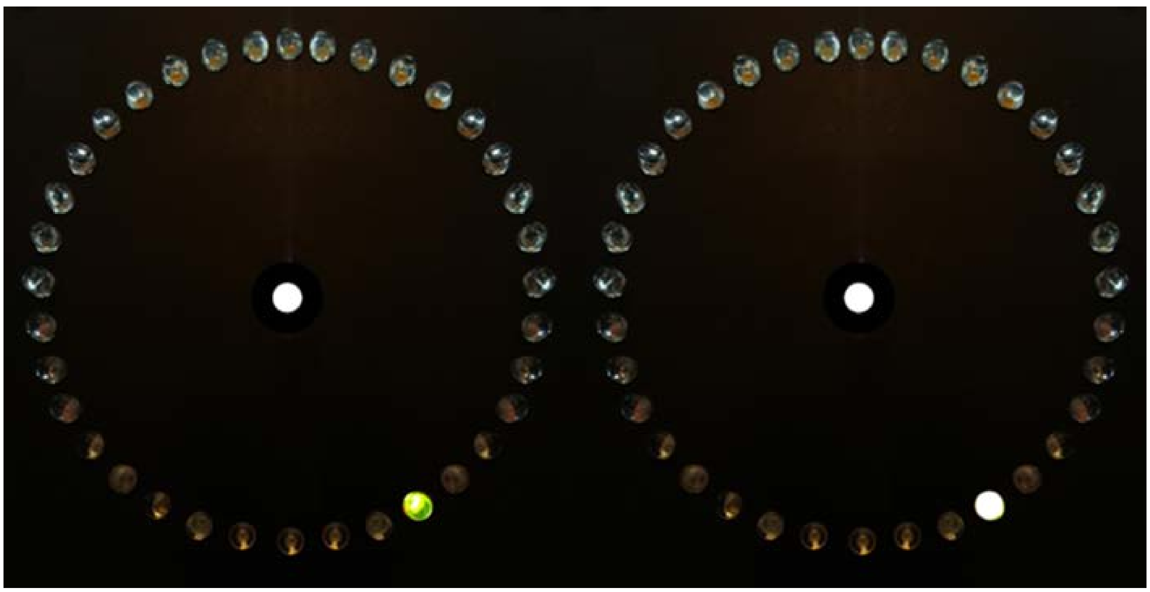

Figure 1. The RGD and single-die LED presentation apparatus.

Results

The effect of LEP glasses on color perception varied based on color and LED type. Highly saturated colors[1] were identified reliably. As colors became desaturated, the color identifications became more ambiguous.

The use of LEP glasses had little influence on perception of green LEDs in terms of either accuracy or RT. The LEP glasses seemed to speed the reaction time on the blue RGB LEDs. LEP glasses seemed to further reduce the reaction time when viewing both RGB and SD LEDs with no effect on accuracy. When comparing SD to RGB LEDs, red SD LEDs with the use of LEP glasses were associated

[1] Saturated colors look “pure.” Highly saturated colors have both high intensity and narrow bandwidth. Desaturated colors have lower intensity, wider bandwidth, or both. Adding white, black, gray, or a color’s complement causes desaturation. A progressively desaturating red, for instance, could look like this:

with an increase in accuracy and a slowing of reaction time. LEP protection significantly reduced the accuracy of identification with white LEDs while exhibiting minimal change in reaction time. The relationship with white SD LEDs was the highest with an accuracy reduction to almost zero. Accuracy of identification of yellow RGB LEDs also declined with the use of LEP glasses with no influence on reaction time. Yellow RGB LEDs resulted in reduced accuracy and reaction time performance in relation to yellow SD LEDs regardless of LEP glass usage.

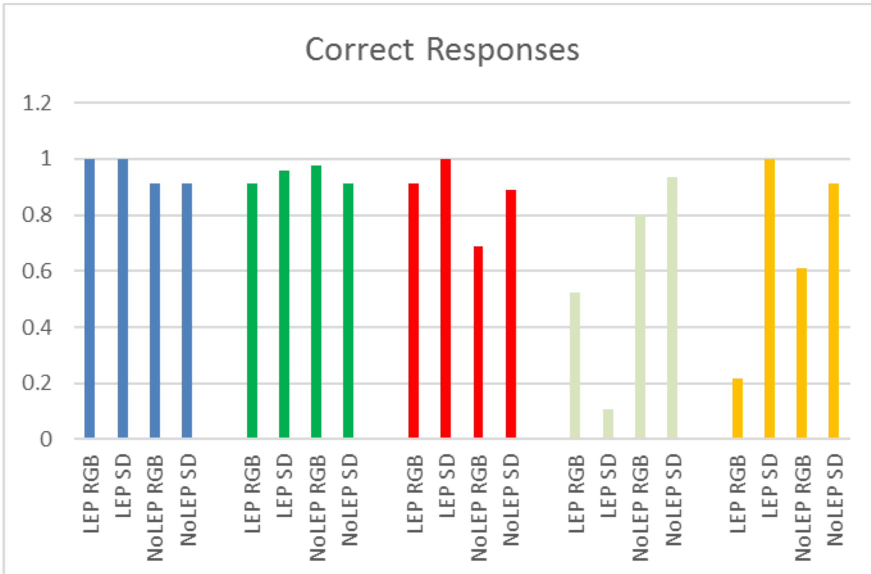

Figure 2. Correct responses of participants color x LED type x LEP

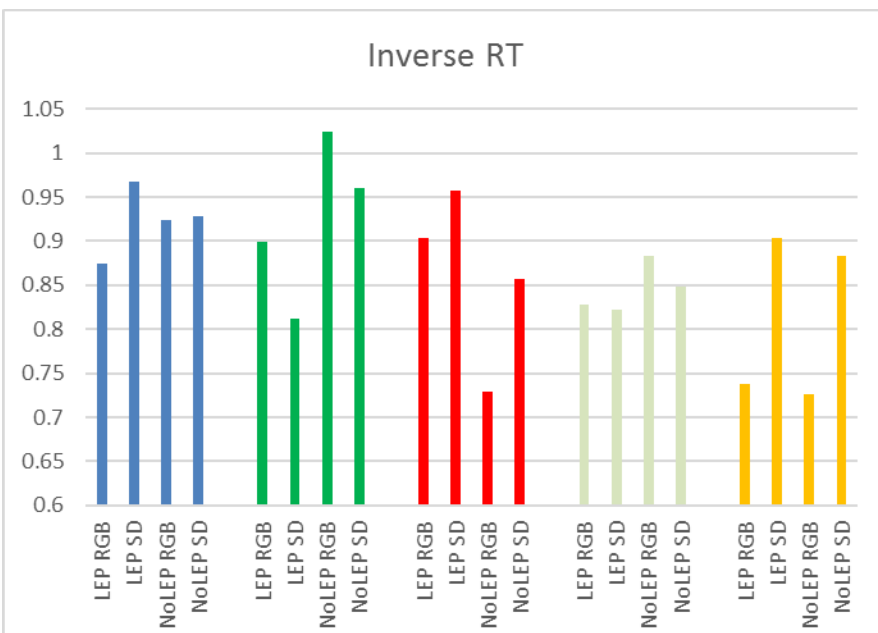

Figure 3. Inverse reaction time of participants color x LED type x LEP

Discussion

The results of this experiment indicate that the effect of LEP glasses on color perception varies based on LED color and LED type. As was anticipated from the method of generating white light from an RGB LED, LEP protection significantly reduced the accuracy of identification. The data indicated a minimal change in reaction time. This may be indicative of a crisp shift in perceived color. The wavelengths reaching the retina potentially present a clear, unambiguous color, albeit different from that initially emitted by the LED. The lack of ambiguity is likely the reason there is little change in reaction time. The participants did not need to evaluate the light carefully to identify the color they perceived. Unexpectedly, the relationship with white SD LEDs was the highest with an accuracy reduction to almost zero. However, unlike many other SD LEDs, white SD LEDs do emit on multiple wavelengths including in the blue and green bands. The filtering of blue and green by the LEP glasses likely shifts the perceived color toward the red end of the spectrum (Figure 2.).

In a manner similar to the white LEDs, identification accuracy of the yellow RGB LEDs declined when viewed through LEP glasses with no change in reaction time. Both with and without LEP glasses, yellow RGB LEDs resulted in reduced accuracy and reaction time performance in relation to yellow SD LEDs.

As the green and blue filters in the LEP glasses do not overlap with the output of the blue LEDs, the use of LEP glasses had little influence on perception in terms of either accuracy or reaction time. Paradoxically, the LEP glasses seemed to speed the reaction time on the blue RGB LEDs. It is possible, though not evident from the available spectral measurements, that the LEP glasses are increasing the saturation of the blue light emitted.

It is also possible that the saturation of red LEDs was increased by the use of LEP glasses, thus, increasing the accuracy but with a slight slowing of reaction time. Generally, saturated colors were easier to identify than desaturated colors. For example, LEDs that were between 600 and 620nm were identified as either red or amber/yellow depending on the observer.

This presents a problem, for instance, when on final approach or during the landing roll if the approach and runway lights have been transformed from a meaningful pattern of white, yellow, green, and red to only a collection of red lights. Other visual cues, such as the general pattern of lights, provide additional information to the flight crew that might offset the loss of color cues. However, during times of high workload, distraction, or degraded visibility such as haze, the additional visual cues may be more difficult to discern and properly interpreted.

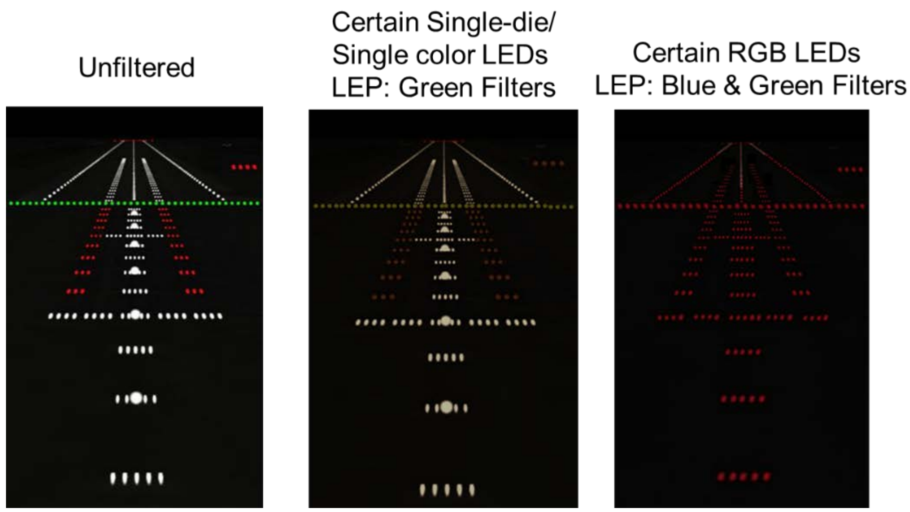

Figure 4. Potential approach light color perceptual challenges base on LED type and LEP filters.

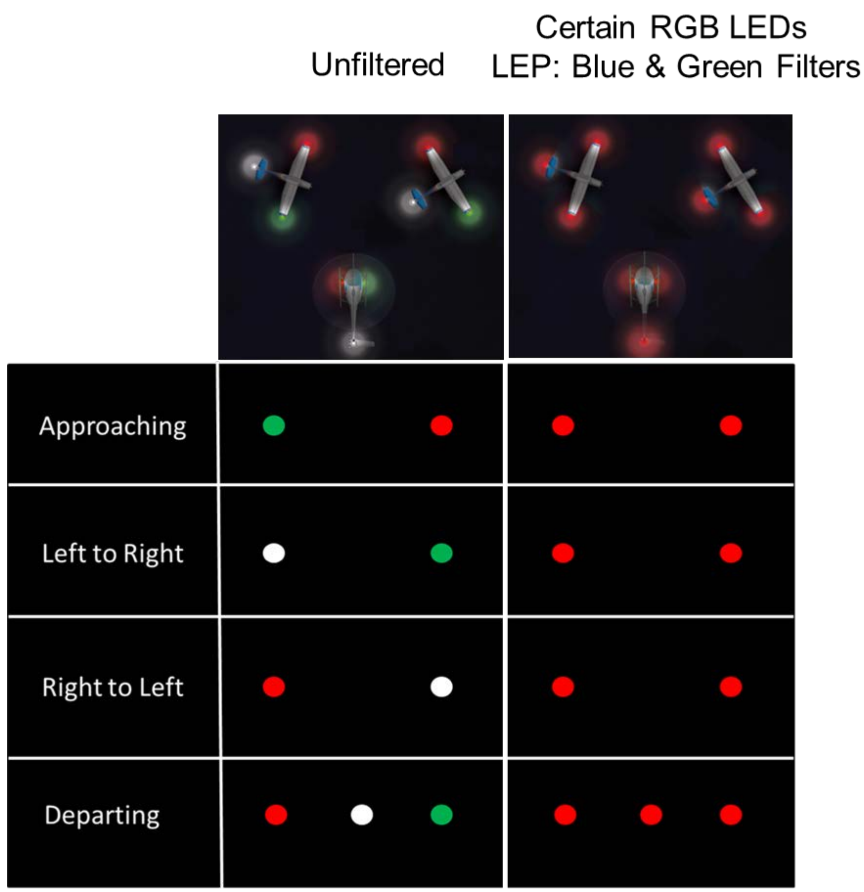

Figure 5. Potential perception of position lights through LEP devices

Conclusion

Aviators are encouraged to familiarize themselves with color perception through their LEP devices prior to flight by viewing lighting in the airport environment prior to departure. During flight operations, pilots are advised to cross-check signal lighting information with other visual cues, ground and traffic warning systems, and flight deck displays. A long-term solution might benefit from the fact that emissions from LEDs are theoretically infinitely tunable during the manufacturing process. This characteristic presents the possibility of manufacturing RGB LEDs that emit in portions of the visible spectrum that are less problematic when using LEP glasses.

References

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