Proposal: An Exploration Of Foveated Bluelight Filters in HMDs

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State of the art head-mounted displays (HMDs) with LED screen technology are known to emit large amounts of short waved, high energized, blue light. A large set of studies has presumed a negative health impact of blue light to the retina and general well-being – assumptions indicate Digital Eye Strain (DES), permanent physical damage to the retina and a disturbed day-night rhythm. With VR being expected to achieve an increasing amount of regular users, we predict a growing complaint about issues based on increased blue light consumption. Recent investigations have shown positive health effects of blue light filters, such as filtering glasses or software. While filtering solutions for PC and Smartphone are already used on the market, filter technology for VR has not yet fully developed. A negative effect of common blue light filters is the loss of User Experience (UX), as colors are not projected correctly but rather are shifted into the red-color spectrum. Using knowledge of the human visual behaviour – such as varying color and light perception on the retina – we want to reduce negative health impact on the user while avoiding negative impacts on UX using foveated bluelight filters based on the concept of foveated rendering. Expected effects like reduced DES and increased well-being have to be investigated in a user study using a VR prototype.

Fig. 1. A schematic representation of how foveated blue light filters might appear in a VR environment. Note that blue light filtering intensifies with increasing distance from the focal area. *src: Julian Karlbauer*

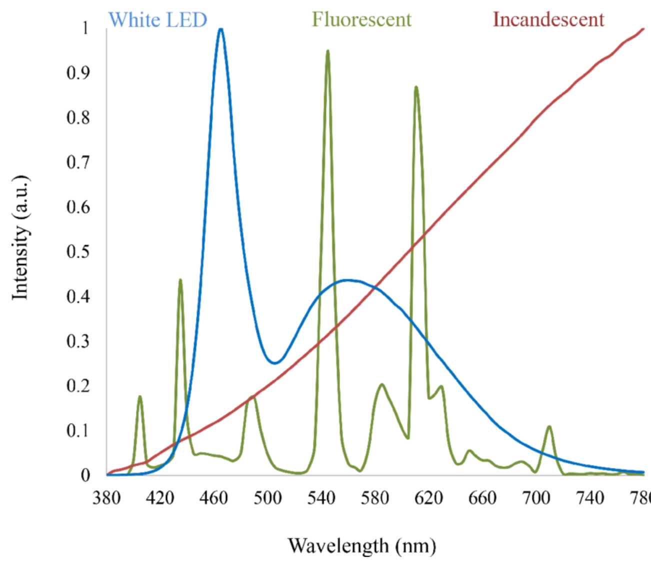

Fig. 2. The wave spectrum of different light sources in comparison. White LED lights show a high peak in the short-waved spectrum, which may be damaging to human eyes under remaining exposure. *src:*(8)

Introduction

Modern LED displays used for smartphones, tablets, monitors, VR etc. emit large amounts of short waved electromagnetic waves $(\lambda \mp 450nm)$ (Fig. 2) that are perceived as blue light by the human eye and might cause a fatiguing effect (1). Recently, a debate about the impact of such light to health and general well-being arose (2). Opinions reach from Apoptosis (cell-death) [(3),(4)] to DES combined with sleep-rhythm issues, based on the circadian rhythm and melatonin production, [(2), (1)] to no critical harm (5) caused by blue light exposure. An overall trend however leans towards the assumption of harmful effects regarding the eye's direct and persistent exposure to short waved light. Assuming a harmful effect, children could suffer particularly, as children's eye lenses are clearer than adult's and allow a significant larger amount of blue light to pass on the retina (6). According to radiation physics, this effect intensifies with decreasing distance between retina and light emitting source, making the use of VR HMDs a worst case scenario. They are not only close up to the eye, but also take over the whole Field Of View (FoV) while common displaying methods (e.g. smartphones, PC monitors etc.) only affect a limited portion of the FoV. Therefore, when fighting blue light exposure, VR HMDs should be granted distinct attention. Spreading the word, leading Tech. companies (Apple, Microsoft & co.) innately implement 'on demand' blue light filtering software into their stationary and mobile operating systems, however – surprisingly – modern HMDs are not yet commonly granted with such functions. An overall positive effect of blue light filtering on well-being can be assumed (7).

Asking why blue light filters are not standard, presumably leads us to User Experience (UX). Filtering out 100% of the blue parts of an image, makes blue spaces appear black and white spaces yellow, which is intriguing when it comes to design. Images are then no longer perceived as they originally were meant to, which makes filtering solutions a trade of concept and therefore rather uninteresting for a majority of the users, while it might be an important step towards a healthier use of computer technology.

The approach of foveated blue light filtering therefore would

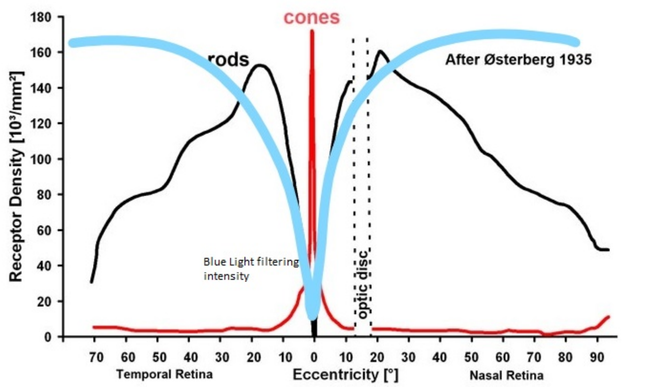

Fig. 3. An overview of rod and cone distribution on the human retina. Added in: a curve to describe the radial intensity of an undetected foveated blue light filter. *Osterberg 1935 – src: https://webvision.med.utah.edu/book/part-iii-retinal-circuits/circuitry-for-rod-cells-through-the-retina/*

be to 1) decrease blue light exposure to a healthier portion while 2) avoid the loss of UX that arises by falsifying the appearance of colors. We are motivated by the concept of Foveated Rendering, which is used to increase system performance by decreasing screen resolution in the peripheral FoV. For our use case not resolution, but color and brightness appearance on different parts of the human retina will be key for our approach, while we also make use of the fact that VR reaches across large parts of our FoV. (Fig. 1). As foundation we rely on the insights that peripheral color(9)- and focal brightness(10) perception are highly restricted. A first literature research has not shown any known projects or concepts using a similar approach, while blue light filtering in general is given reasonable attention.

Approach

A vague glance on cone-cell (i.e. color perception) and rod-cell (i.e brightness perception) distribution reveals that cones are enriched in the center *(fovea)* while rods dominate peripheral parts of the retina. In particular, at a certain degree no rods are found in the fovea while only a very limited amount of cones is placed in outer peripheral areas of the retina (Fig. 3). Consequently, color perception in the outer periphery and brightness perception in the central fovea – in basic – are biologically impossible. While luminance and contrast processing via cone opponency (11) in the human brain making the concept more complicated, the basic idea remains (9). Therefore, we assume that it should be able to cancel out blue light portions down to $50°$ (9) of the peripheral FoV in a HMD without the perception of the user in terms of color. A low fidelity prototype containing a white screen with peripheral red-shift will give further evidence – filtering can be more intense in the far periphery (Fig. 3) *(blue curve)* as it basically describes the mirrored cone function. Using a foveated rendering algorithm and manipulating individual pixel color will then provide us the possibility to foveatedly reduce blue light exposure in the peripheral FoV. Presumed, a 70% blue light reduction in the far periphery and a 30% blue light reduction in the mid periphery is possible without a loss of UX, we would approximately reach an overall blue light reduction of $\geq 33\%$ in the whole FoV without the recognition of the user. It might be concerning that the fovea would still be fully exposed to 100% of the blue light, which further investigations need to conquer. An approach would be to reduce general brightness in the focal area *(lowering the blue curve amplitude in Fig. 2)* and therefore also reducing blue light portions. Here we take a lack of proper brightness perception in the central FoV to our advantage (10). Hardware wise, eye tracking technology and a VR setup are necessary. The HTC VivePro Eye can provide everything needed. In a user study we want to evaluate the effect of foveated blue light filtering. Our research questions are: *1) Are DES effects reduced by applying blue light fitlers in VR?* followed by *2) to what extent do users notice differences between a foveated and a control approach?* and *3) to which degree do users accept blue light filtering in general and in comparison to a foveated approach?*. Overall, we hope to achieve new insights in how (foveated) blue light filtering can be applied for VR HMDs and to what extent DES can be reduced by applying these filters. Further, we aim for insights in UX, regarding different blue light filtering approaches.

Arrangement

This work is planned to be executed within a time window of 3 - 4 months. However, registration is planned for 6 months to contain buffer. Implementation will be granted one month but can presumably be finished earlier. Another month is reserved for study development, execution & evaluation so that one month of collecting & writing remains.

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