Museum Lighting, Colour Constancy and Melanopsin

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I, Daniel Garside, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the work.

Abstract

Insert abstract

Impact Statement

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Acknowledgements

Acknowledge all the things!

I also wish to note my appreciation and thanks to the various pieces of open source software I used in the writing of this thesis. For further details see Appendix C.

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Chapter 1

Introduction

Light causes damage to objects in museums. Museums seek a pragmatic compromise between lighting which causes minimal damage to objects, and lighting which allows maximal visitor enjoyment. Generally this is achieved by following industry recommendations for maximum illuminance and colour rendering index.

A complementary way to reduce damage, highlighted by the Commission Internationale de l'Eclairage in a 2004 publication, is to choose illumination of a lower Correlated Colour Temperature (CCT), because such illumination will contain most radiation energy in the longer wavelengths, which are generally less damaging to objects. Computations performed for a range of commercially available lighting products showed a strong correlation between predicted damage and CCT, with a factor of two between the low and high CCT sources. Practically, a sensitive object might be displayed for twice as long under a low CCT illuminant than a high one, before passing a damage threshold.

A series of interviews with museum professionals showed that this technique is not currently being employed. One reason is a belief that changing the CCT in an environment will affect the visual experience and the atmosphere in the room.

Models of vision suggest that a change in CCT alone should not affect visual experience; that in a space with a single type of lighting we should be able to adapt to any colour of illumination. This seems at most only partially true. It is true that we adapt reasonably well to the ambient illumination, both in terms of luminance and chromaticity, such that our perception of object colours relates primarily to

object reflectance properties rather than the absolute intensities reaching our eyes. Generally, however, we do also seem to have an awareness of the properties of the illumination in a scene, and even a preference for some sources over others. Historically, experiments seeking to find an ideal preferred CCT have provided conflicting results.

One possible reason for these conflicting results might be that an additional retinal mechanism is involved in chromatic adaptation. The studies in this thesis have investigated whether a cell group called the intrinsically photosensitive Retinal Ganglion Cells (ipRGCs) might be involved in colour constancy. This cell group has traditionally been considered as having no output to visual pathways, and so colour constancy experiments haven't controlled for intrinsically photosensitive Retinal Ganglion Cell (ipRGC) activation, but recent research has shown that ipRGCs do in fact have a limited input to visual pathways. There are a range of reasons that suggest that they may play a role in colour constancy specifically.

To investigate the effect of different levels of ipRGC activation on an observer's state of colour constancy, two lab-based psychophysical experiments were performed. The first sought to examine the effect of different wavelengths of light upon chromatic adaptation. Within a Ganzfeld viewing environment, illuminated by one of 16 different wavelengths of near-monochromatic light, observers performed an achromatic setting task, controlling the chromaticity of a display visible in the central field through a 4° circular aperture with two handheld sliders.

In the second experiment the role of melanopsin in chromatic adaptation was more directly questioned. The same task was performed as in the first experiment, but the Ganzfeld was this time illuminated by one of two perceptually metameric lights with different melanopic irradiance levels. Neither of these experiments provided evidence for a simple or strong effect of ipRGC activation, though this is limited to the case where peripheral stimulation would affect central perception.

Concurrently, a method has been developed for performing colour constancy experiments outside of the lab environment, which can be completed quickly by naive observers in 'real-life' illumination conditions. The method uses a tablet com-

puter, on which an isoluminant plane through CIELUV is presented, successively varying in orientation and spatial offset. The observer is tasked with selecting, by touching with a finger, an achromatic point from within each stimulus. From the recorded selections an estimate of the observer's state of chromatic adaptation is computed.

Following these experiments a different approach was adopted: rather than asking what was the affect of varying ipRGC activation upon experimental subjects, instead the question was posed whether an ipRGC-based signal could hypothetically be useful for colour constancy, considering what we know of daylight variability and natural surface reflectance properties. A computational methodology was employed. It was found that the spectral sensitivity of melanopsin is optimal for providing a signal that can transform raw chromatic signals to an illuminant-independent space, and that this can be done without using any scene level assumptions such as grey-world.

The applied goal of this research was to increase our understanding of colour constancy so as to advise museums on how to reduce damage to objects without degrading visitor experience. Asking whether ipRGCs play a role in colour constancy is additionally valuable to the vision science community, and to lighting engineering applications beyond the museum world.

Chapter 2

Literature Review

2.1 Colour Science

2.1.1 Illumination and Colour Vision

2.1.2 Colorimetry and Colour Measurement

Colorimetry is the study of the quantitative specification of colour. As a subjective, internal and anthropocentric concept, in order to measure anything meaningful and comparable, we use a standard observer, or more precisely, one of a number of defined standard observers [1].

The classic standard observer was defined by the CIE in 1931, following experiments by Wright and Guild [2, 3]. Despite several more recently published standard observers, the 1931 observer is still much used, and I shall use it in the following example of how a basic colorimetric computation is performed.

An illuminant is defined by its spectral power distribution (SPD), a surface as it's spectral reflectance function (SRF), and a the sensitivity of a sensor (such as a photosensitive cell in the retina, or a pixel in a camera) by its spectral sensitivity function spectral sensitivity function (SSF).

The light reaching (colour stimulus (?)) the eye for a given surface under a given illuminant can be computed by multiplying the SPD by the SRF at each sampled interval.

Equation

From this tristimulus values can be computed.

2.1.3 Colour rendering and light quality specification

2.2 Museum Lighting

2.2.1 Current practise in specifying museum lighting

2.2.2 Balancing conservation with observation

2.2.3 Damage factors

2.2.4 LEDs in museums

2.2.5 New opportunities with solid state lighting

2.3 Chromatic Adaptation and Colour Constancy

'Adaptation' is the general mechanism by which a finite range of sensitivity can be shifted in terms of absolute sensitivity bounds. The benefit of having an adaptive system, as opposed to a fixed system, is that the sensitivity of the system to small changes is maximised, whilst maintining a broad overall sensitivity, at the expense of being able to sense over the entire range at a single timepoint.

In an environment such as the terrestrial environment, there is a great range in the level of illumination, but this range is rarely existent contiguously; levels of illumination tend to similar across a scene, and only change rather slowly. The notable exception, and thus where we notice the expense of having an adaptive visual system, comes when we enter or exit an environment where illumination is almost entirely excluded, such as a dark cave or below decks of a boat.

[pirate eyepatch image?]

Lighthness adaptation

Chromatic adaptation

2.4 Intrinsically Photosensitive Retinal Ganglion Cells

2.5 Research questions and hypothesese

Chapter 3

Large Sphere

Some stuff about things.[4] Some more things.

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Chapter 4

Small Sphere

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Chapter 5

Computational Study

Some stuff about things.[4] Some more things.

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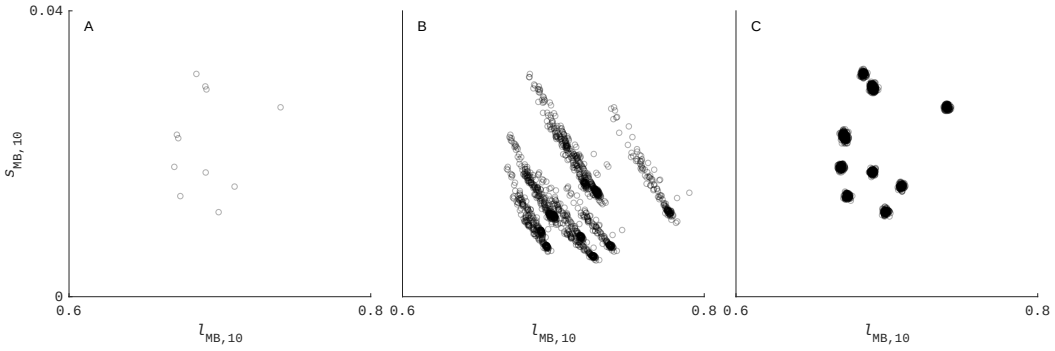

Figure 5.1: Caption

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Chapter 6

Tablet Method

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Inline citation:

Testing cross referencing across chapters. I said a thing in Chapter 3 which might be relevent here.

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Chapter 7

General Conclusions

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Appendix A

An Appendix About Stuff

(stuff)

Appendix B

Another Appendix About Things

(things)

Appendix C

Colophon

This document has been written with LaTeX, within a mix of TeXworks (locally) and Overleaf (when online), based on a template provided by !!!!!!!! (available via !!!!!!!). In addition to the packages used in the template, additional use was made of package 'libertine', which loads the Linux Libertine and Linux Biolinum font families (check this!!!!!!!!!!) (which is an open !!!!!!!! font, read more here: !!!!!!!!!!) and 'microtype' which !!!!!!!!!!!

Zotero and BibTeXwere used for reference management. During writing git was used as a version control software, syncing to Github. See this thesis as a github repo here: !!!!!!!!!!

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