

Museum Lighting, Colour Constancy and Melanopsin

Daniel Garside

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
of
University College London.

Civil, Environmental and Geomatic Engineering
University College London

April 29, 2019

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

Insert Impact Statement

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 C.

Contents

1	Introduction	15
2	Literature Review	19
2.1	Colour Science	19
2.1.1	Illumination and Colour Vision	19
2.1.2	Colorimetry and Colour Measurement	19
2.1.3	Colour rendering and light quality specification	19
2.2	Museum Lighting	19
2.2.1	Current practise in specifying museum lighting	19
2.2.2	Balancing conservation with observation	19
2.2.3	Damage factors	19
2.2.4	LEDs in museums	19
2.2.5	New opportunities with solid state lighting	19
2.3	Colour Constancy and Chromatic Adaptation	19
2.4	Intrinsically Photosensitive Retinal Ganglion Cells	19
2.5	Research questions and hypotheses	19
3	Computational Study	21
4	Tablet Method	23
5	Large Sphere	25
6	Small Sphere	27

7 General Conclusions	29
Appendices	30
A An Appendix About Stuff	31
B Another Appendix About Things	33
C Colophon	35
Bibliography	36

List of Figures

3.1	Caption	21
-----	-------------------	----

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 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

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 Colour Constancy and Chromatic Adaptation

2.4 Intrinsically Photosensitive Retinal Ganglion Cells

2.5 Research questions and hypotheses

Chapter 3

Computational Study

Some stuff about things.[1] Some more things.

Inline citation: Anne Author. Example Journal Paper Title. *Journal of Classic Examples*, 1(1):e1001745+, January 1970

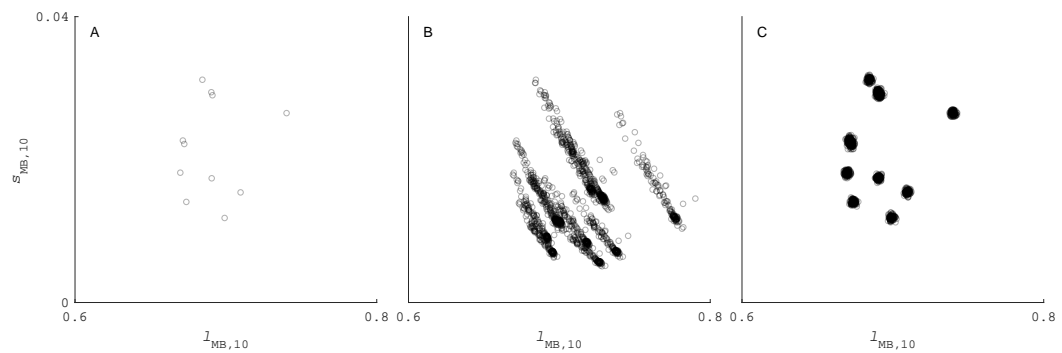


Figure 3.1: Caption

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

Chapter 4

Tablet Method

Some stuff about things.[1] Some more things.

Inline citation: Anne Author. Example Journal Paper Title. *Journal of Classic Examples*, 1(1):e1001745+, January 1970

Testing cross referencing across chapters. I said a thing in Chapter 5 which might be relevent here.

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

Chapter 5

Large Sphere

Some stuff about things.[1] Some more things.

Inline citation: Anne Author. Example Journal Paper Title. *Journal of Classic Examples*, 1(1):e1001745+, January 1970

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

Chapter 6

Small Sphere

Some stuff about things.[1] Some more things.

Inline citation: Anne Author. Example Journal Paper Title. *Journal of Classic Examples*, 1(1):e1001745+, January 1970

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

Chapter 7

General Conclusions

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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 Bib \TeX were 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: !!!!!!!

Bibliography

- [1] Anne Author. Example Journal Paper Title. *Journal of Classic Examples*, 1(1):e1001745+, January 1970.