I've jokily added the previously known as bit because for quite a lot of this presentation it won't seem like I'm giving the presentation with this title, but bear with me, we'll get there.

The reason for that is this:
Links between vision research and lighting research.
Take a step back, and give an overview of the overall narrative, the logic flow, of my phd.

Overview

1. Museum lighting
2. Damage functions
3. Colour Temperature
4. 'Preference' prediction
    1. Kruithof
    2. Colour rendering
    3. Melanopsin
5. *My research*

Museum lighting:

Necessary to see objects

but

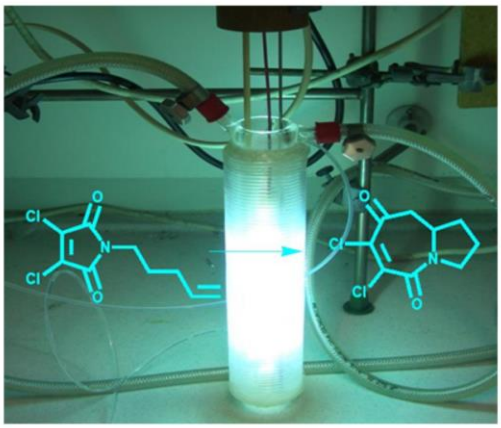
damages objects over time

Close up of light damage on musician Wilf Carter's bright pink suit from NMC's Canadian Country Music Hall of Fame collection. Credit: Gail Niinimaa
https://nmc.ca/who-turned-out-the-lights/

- As we can see, this is frankly a disaster; it has the power to turn what was once an truly stunning suit into a rather drab, and un-matching, pile of sadness.

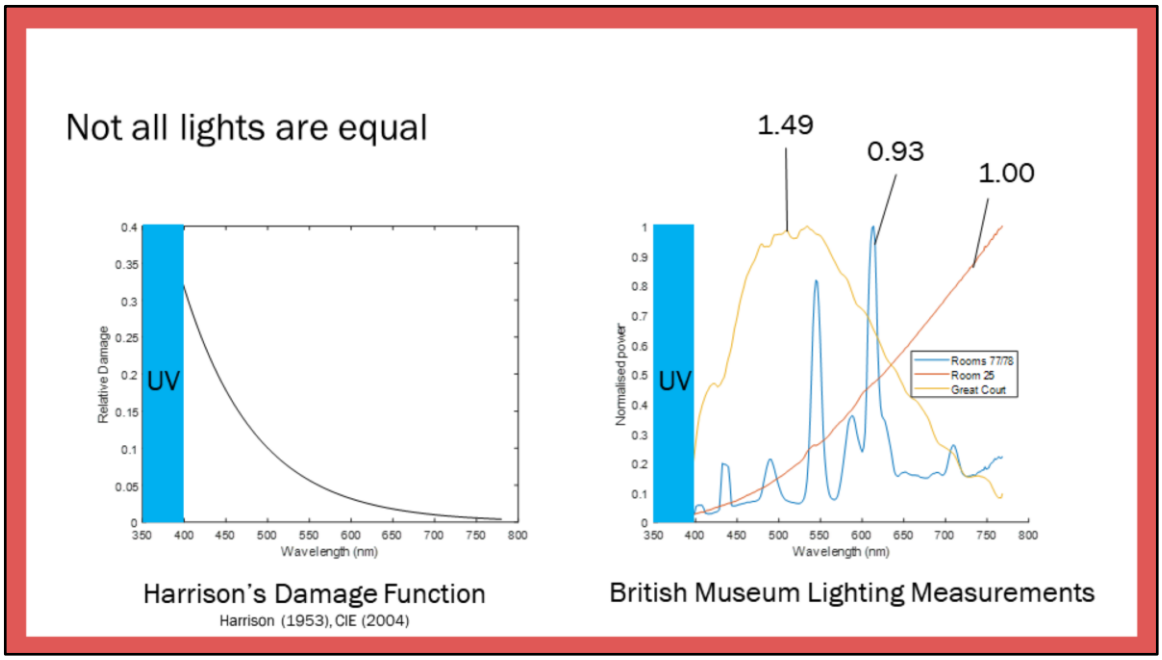
What is it about light that causes damage to objects?

Photodegradation



https://chemicalengineeringmatters.files.wordpress.com/2014/12/photochemical-reaction.jpg

- Provision of energy through light, to make a chemical reaction happen



- UV is the real bad guy, easy win because it's invisible, we get rid of it, no-one notices (now standard practice)
- Controversial, because each material has it's own damage function, dependent on material and various other environmental conditions such as humidity and temperature.
    - In a museum with many different types of object, what's the value?

Damage functions

Saunders, D., Kirby, J., 1994.
Wavelength-dependent fading of artists' pigments.
Studies in Conservation 39, 190–194.

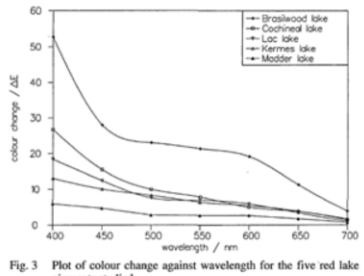
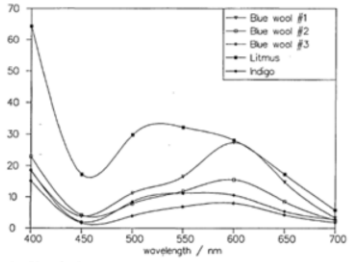


Fig. 3 Plot of colour change against wavelength for the five red lake pigments studied.



Plot of colour change against wavelength for litmus, indigo and the blue wool standards.

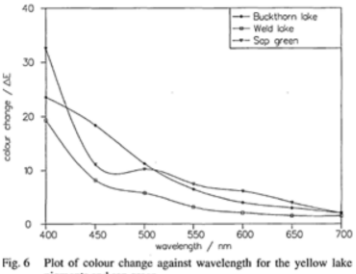


Fig. 6 Plot of colour change against wavelength for the yellow lake pigments and sap green.

- DI is an average, but does it mean anything?
- It applies most well to objects which absorb and reflect most wavelengths relatively equally, white paper for example.
- It is much trickier to apply it to objects which absorb and reflect different wavelengths preferentially, or in other words, coloured objects.
    - Grotthuss-Draper law, damage can only be caused where light is absorbed
    - Thornton lamp, Durmus thesis
- But let's have a look at multiple damage functions, for different materials

Damage functions

Nakagoshi, K., Yoshizumi, K., 2011.
Degradation of Japanese Lacquer under Wavelength Sensitivity of Light Radiation.
Materials Sciences and Applications 2, 1507.

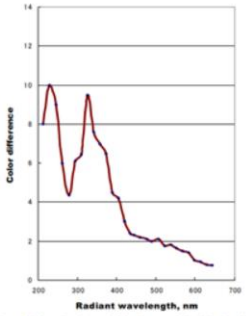


Figure 8. Wavelength sensitivity characteristics for the fading of Tame-Urushi under a radiant energy of 5 MJ/m²/nm at each wavelength.

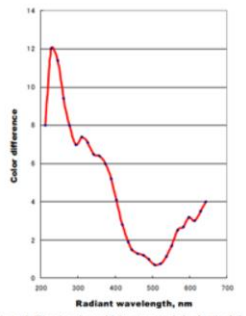


Figure 9. Wavelength sensitivity characteristics for the fading of Shuurushi under a radiant energy of 5 MJ/m²/nm at each wavelength.

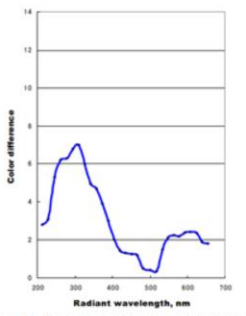


Figure 10. Wavelength sensitivity characteristics for the fading of Ao-Urushi under a radiant energy of 5 MJ/m²/nm at each wavelength.

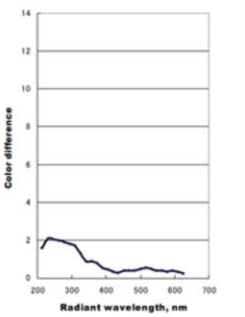


Figure 11. Wavelength sensitivity characteristics for the fading of Shin-Urushi under a radiant energy of 5 MJ/m²/nm at each wavelength.

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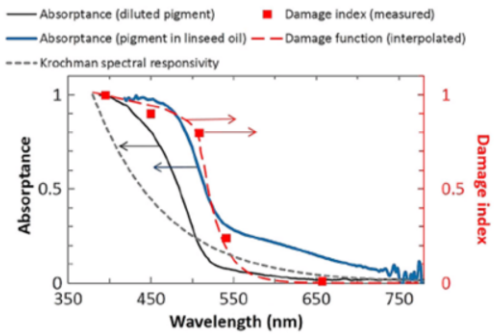
Damage functions

Lunz, M., Talgorn, E., Baken, J., Wagemans, W., Veldman, D., 2017.
Can LEDs help with art conservation?
– Impact of different light spectra on paint pigment degradation.
Studies in Conservation 62, 294–303.
doi.org/10.1080/00393630.2016.1189997



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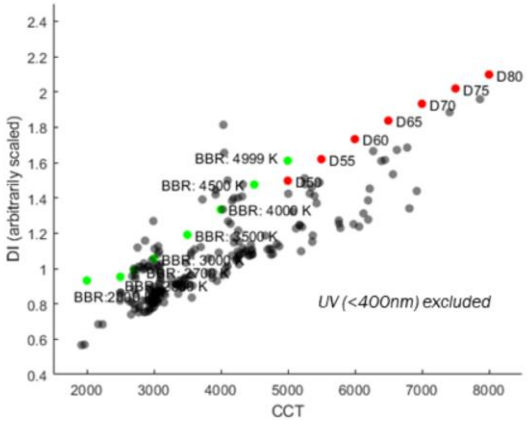
Damage indexes for different light sources



- Let's just assume for a moment that I've convinced you of the utility of an average object damage function, let's have a look at some predictions it makes for available lighting
- We do see a trend
- If we compare a light source from this clump around (3000, 0.8) and one of these higher ones (6500, 1.6) we notice that this is a doubling of damage potential.
- That's a doubling of lifetime of an object, or a doubling of the amount of time it can be displayed.
- That seems worth caring about.

- Vision models would suggest that these are the same
- But some are preferred to others, and we're not quite sure why.

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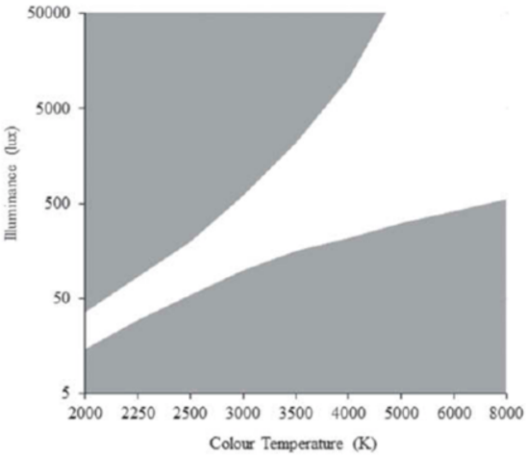
Visual effect of different CCTs

'Kruithof curve'

Fotios, S., 2017.
A Revised Kruithof Graph Based on Empirical Data.
LEUKOS 13, 3–17.
doi.org/10.1080/15502724.2016.1159137

Kruithof, A.A., 1941.
Tubular luminescence lamps for general illumination.
Philips tech. Review 6, 65–96.



- Fotios meta-study. Looked at 29 studies, concluded that 9 provided credible data.
- Found that of those 9, there was no strong support.
- An interesting idea came up in published responses from the article: that maybe we're not asking quite the right questions, and also that maybe the questions we think we're asking aren't the ones being answered.
    - Cuttle hotel example

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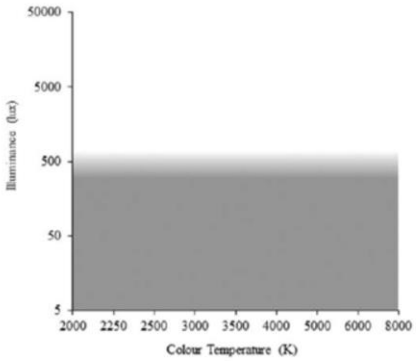

Cuttle, C. 'Kit,' 2017. ***Review of a Published Article.*** *LEUKOS 13, 19–20.*
https://doi.org/10.1080/15502724.2016.1187910

Fotios, S., 2017. ***Author's Reply to Review of a Published Article.*** *LEUKOS 13, 21–22.*
https://doi.org/10.1080/15502724.2016.1187911

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Visual effect of different CCTs

One reason for disagreement between studies is an imprecise specification of the SPD of the light sources.

...

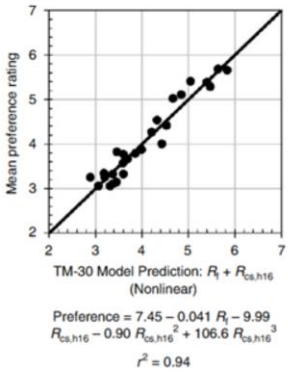
"Lighting designers continue to refer to it with reverence . . . " [Cuttle 2015], which suggests that there is something regarding the interaction of SPD and illuminance still to be teased out. Further work would be interesting if it explored SPD metrics beyond CCT.

Colour rendering

CIE (R_a)

↓

IES TM-30-15 (R_f / R_g)



Royer, M., Wilkerson, A., Wei, M., Houser, K., Davis, R., 2016. ***Human perceptions of colour rendition vary with average fidelity, average gamut, and gamut shape.*** *Lighting Research & Technology 1–26.* https://doi.org/10.1177/1477153516663615

One area where people have been thinking a great deal about the reduction of the many-dimensional spectrum into fewer dimensions is the world of colour rendering. Here, the implicit purpose is to communicate how good a light source is, as efficiently as possible.

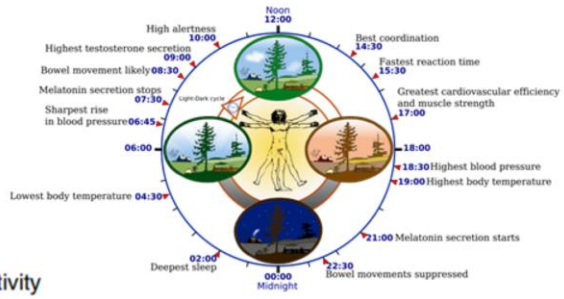
The incumbent Ra received criticism on many fronts. The most boring, but probably the only one that anyone will ever be able to agree on, was that the maths was out of date. It used out of date colour spaces.
The replacement looks set now to be IES TM-30-15, and one of the neat things about this metric is that it uses a great deal more (99) reflectance samples in it's calculation, which gives us a framework to ask more interesting questions than we could before.

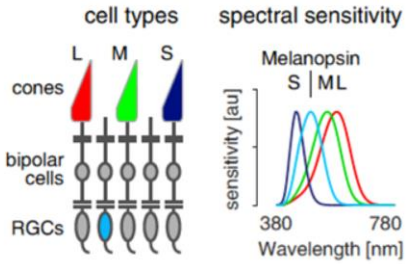
To pull out one such example: Royer found, in a post hoc analysis, that he could predict preference for light sources really well by taking a combination of the average fidelity measure and Rcsh16.
For those of your who don't speak colour rendering jargon, that means that we like it when reddy-purples are increased slightly in saturation.

I think that there might be great promise in this type of research.

Melanopsin

Circadian rhythms



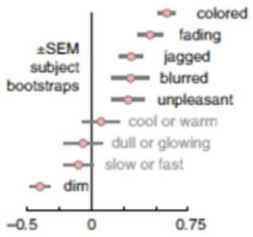


https://en.wikipedia.org/wiki/Circadian_rhythm#/media/File:Biological_clock_human.svg
Spitschan et al., 2017. PNAS 114, 12291–12296. https://doi.org/10.1073/pnas.1711522114

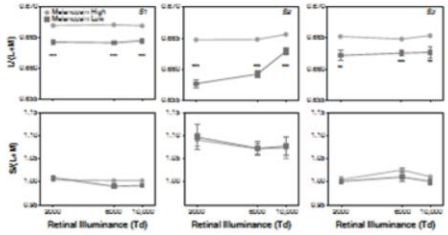
- Melanopsin – found when people were looking for something which controls our circadian rhythm
- As Mariana Figueiro said yesterday, it's likely that ipRGCs combine various inputs as well as their own photosensitivity
- Assumed initially to be non-image forming (we've been doing colorimetry and photometry fine for ages, thank you very much)

Interactions between visual and non-visual systems?

Spitschan, M., Bock, A.S., Ryan, J., Frazzetta, G., Brainard, D.H., Aguirre, G.K., 2017.
The human visual cortex response to melanopsin-directed stimulation is accompanied by a distinct perceptual experience.
PNAS 114, 12291–12296.
https://doi.org/10.1073/pnas.1711522114



Cao, D., Chang, A., Gai, S., 2018.
Evidence for an impact of melanopsin activation on unique white perception.
J. Opt. Soc. Am. A, JOSAA 35, B287–B291.
https://doi.org/10.1364/JOSAA.35.00B287



- But recently there's been a few papers that have seemed to show evidence to the contrary
- I'll highlight two here

Chromatic Adaptation and melanopsin – why?

- Spatial
- Temporal
- Absolute
- Downstream

And why do we *care?*

We think that colour constancy uses **multiple cues*.**
If one of them uses a melanopic signal and this conflicts with other cues, this would probably result in a percept of '**unnatural**', and quite possibly '**unpleasant**'.

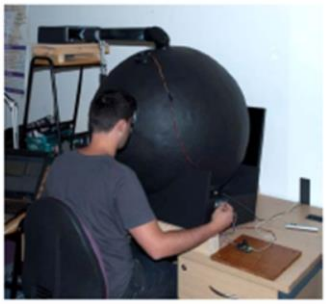
* Kraft, J.M., Brainard, D.H., 1999. Mechanisms of color constancy under nearly natural viewing. Proceedings of the National Academy of Sciences 96, 307–312.

- So why do I think that it might be a contender for chromatic adaptation?
- Well, the spatial and temporal qualities are on the right track – they're both lousy
- They seem as a population to signal absolute rather than relative light levels
- And they're downstream from the traditional visual receptors, which means that they would be well placed to calibrate the signal that they receive

- (which under natural illuminants would be a reliable cue)

Experimental work:

1. Computational (VSS 2018): doi.org/10.6084/m9.figshare.6280865.v1
2. Psychophysics in lab (ICVS 2017): icvs2017.fpvu.de/wp-content/uploads/2016/09/ICVS2017_Abstract-Book-1.pdf
3. Psychophysics in real world (AIC 2016): doi.org/10.6084/m9.figshare.4269680.v1



- Strong correlation for natural light
- Not so much for artificial lighting

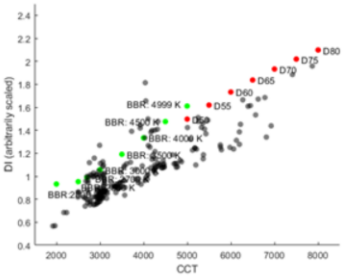
- Elements that make it good candidate for CA: speed, spatial, absolute (population) (pubs drop)

Conclusion:

If we can work out exactly what we do and don't like about lighting,

that gives us much improved tools to decide on lighting which is

both minimally **damaging** and maximally **pleasing.**



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Lindsay MacDonald – CEGE, UCL
Kees Teunissen – Philips Lighting Research
Stuart Robson – CEGE, UCL
Katherine Curran – ISH, UCL
Capucine Korenberg – British Museum

Funders:
EPSRC
Philips Lighting Research

EPSRC
Engineering and Physical Sciences Research Council

PHILIPS

The British Museum

Hidden slides

Studies have found 'preference' for:

- 3700K (Scuello et al., 2003)
- 5100K (Pinto, Linhares, Nascimento, 2008)
- 2900-5950K (Liu et al. 2013)
- 5500/5700K (Nascimento and Masuda, 2014)

Although there are some studies suggesting that for occidental viewers a correlated colour temperature (CCT) of about 5000K is optimal for visual appreciation there is not yet general agreement in the museum community about this issue.

S. Nascimento, J. Linhares, C. Herdeiro, T. Kondo, Y. Misaki, and S. Nakauchi, 2017
"Influence of cultural factors in preferred illumination for paintings"
in "Book of Abstracts, Museum Lighting Symposium and Workshops", 49,
https://doi.org/10.14324/000.bk.10048078, **also:** https://youtu.be/_LD-XvBMfW0

The general trend seems to be for higher CCTs, around 5000K
There has been a great range in the found preferences
The advice from Fotios might be particularly apt here