Low Vision Lighting: Its Important But How Important?

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Disclaimer & Acknowledgement

- I will speak about the LuxIQ from Jasper Ridge. I am a research consultant for Jasper Ridge.
- My research was approved by and conducted in accordance with regulations of VA Palo Alto Research Service and the VA/ Stanford Institutional Review Board.
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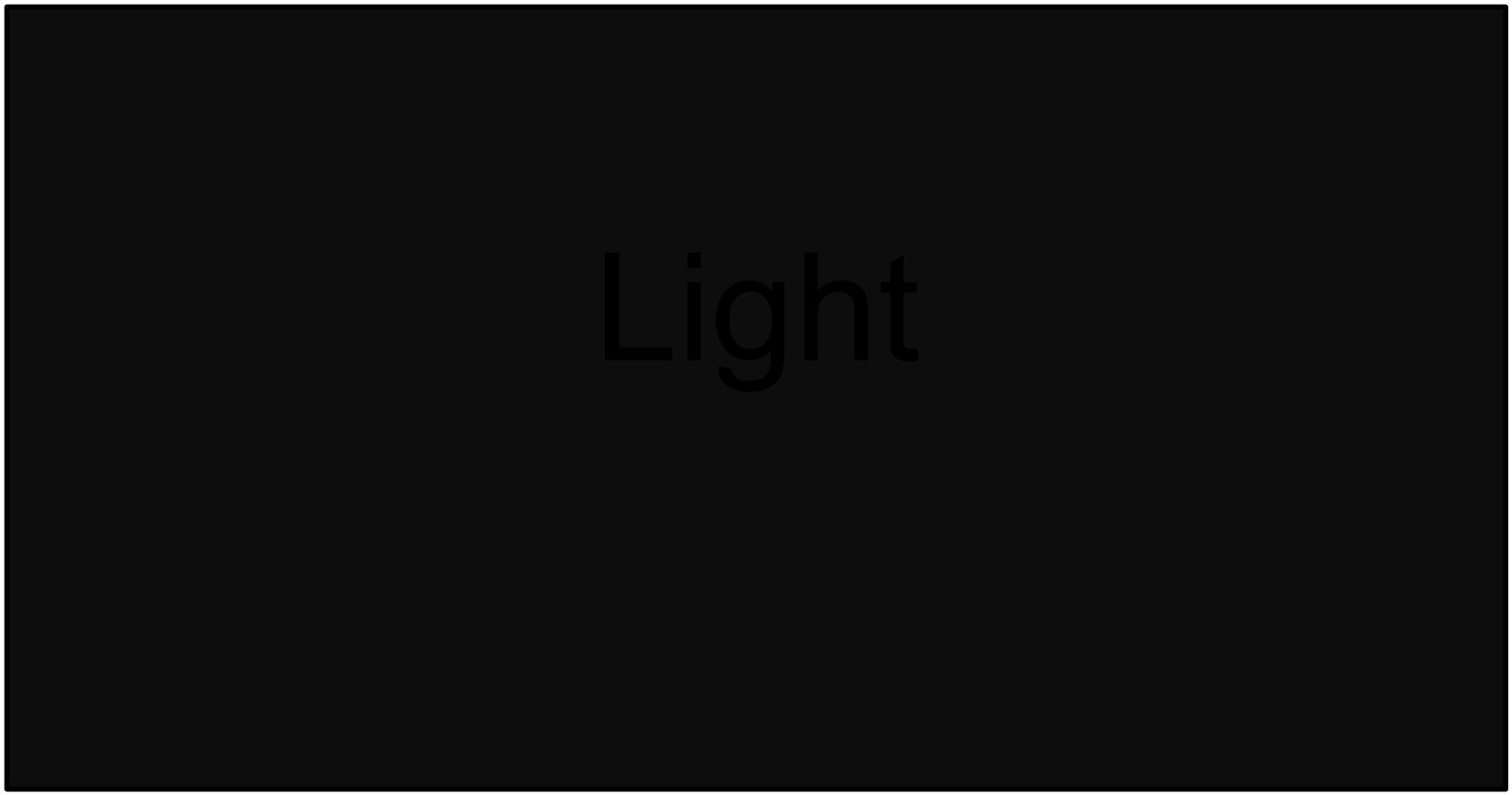
Light is really important



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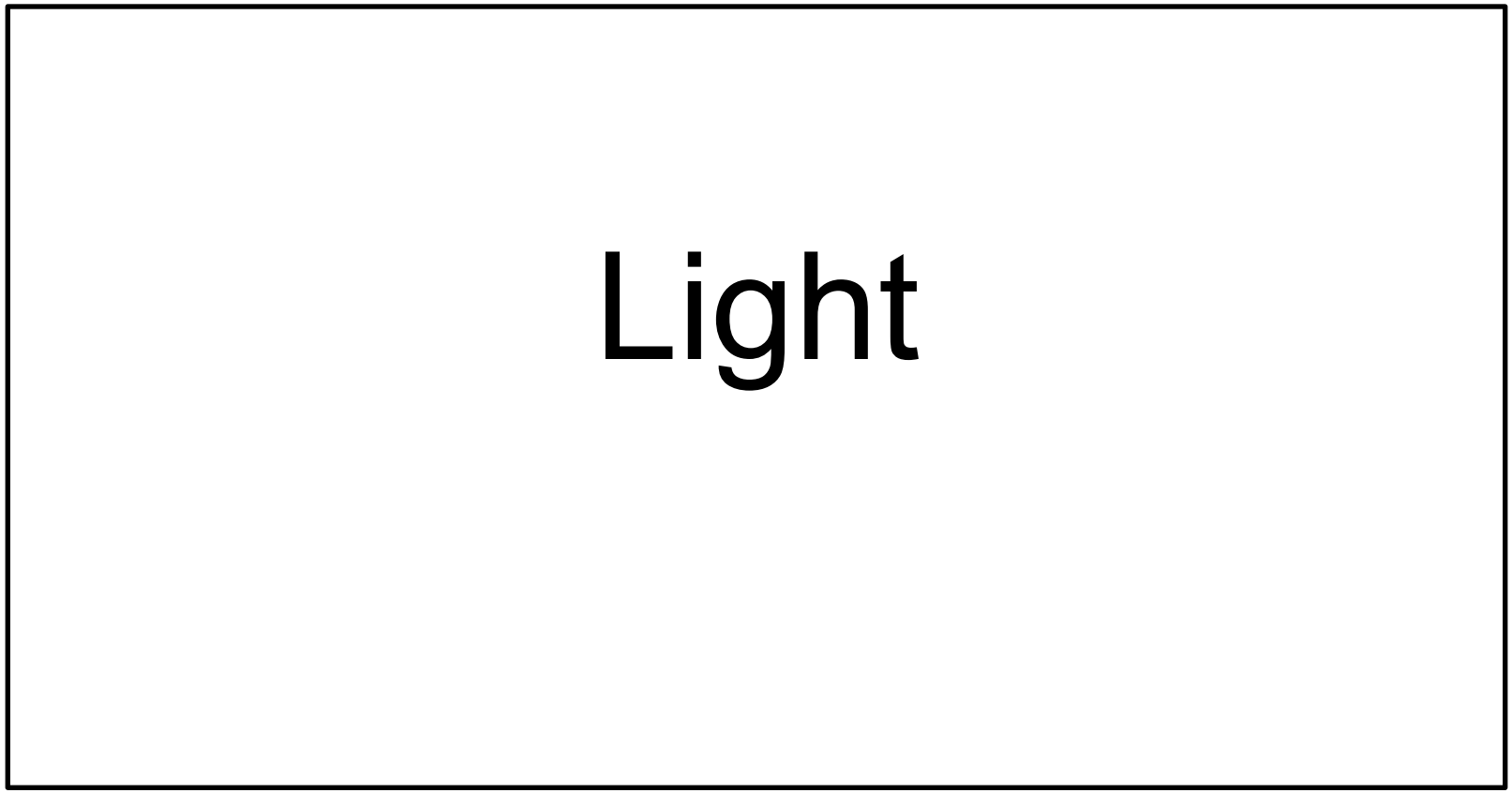
There is an “optimum”



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www.freshnessmag.com

What is “optimum” lighting?

- Optimum lighting is important in maximizing visual function
  - For many, but not all, low vision individuals “more” light is better
    - may add ~2 lines of visual acuity
  - May improve the benefit of optical prescription
- Optimum lighting varies from person to person
  - Not simply “more” light
  - Brightness not only factor; color, color temperature, glare, etc.
- As with refractions, lighting can be measured and quantified
  - Need calibrated, fast, easily used measurement tool

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The “Curse” of Terminology

I didn’t really understand lighting until I began to understand the terminology.

Turns out it isn’t all that difficult once you have some clarification.

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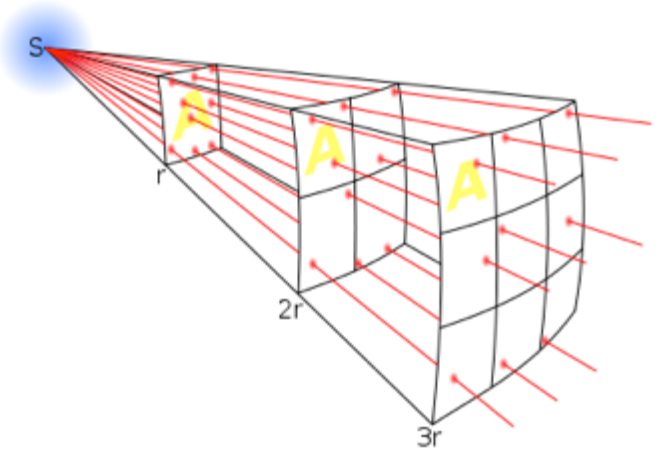
Who needs better lighting?

- Normally sighted
  - Reading in dim light
  - Threading needle
  - Working in tight spaces
  - Etc.
- People with visual impairments
  - Most with central field loss
  - Most with peripheral field loss
  - Some with traumatic brain injury
- Better light involves brightness, color, glare, distribution



www.e-education.psu.edu

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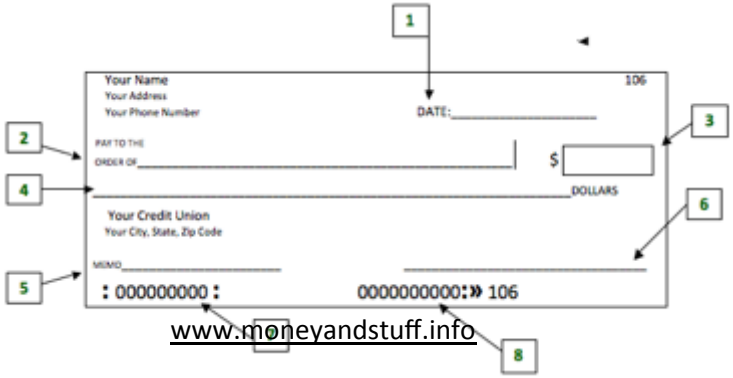
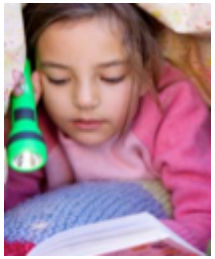
Where do we need optimized lighting?

- Reading pill bottles
- Reading for work, school, & enjoyment
- Cooking & hobbies
- Finances - writing checks & reading bills
- Etc.

www.consumerreports.org



www.moneyandstuff.info



health.howstuffworks.com

www.pinterest.com

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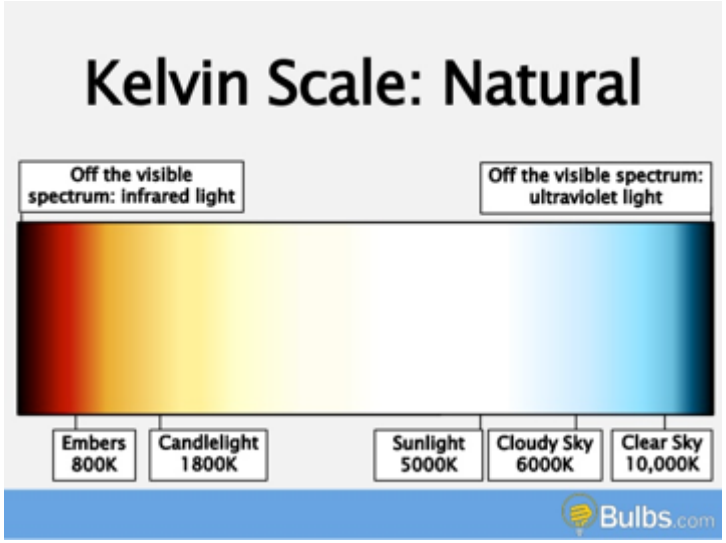
Task vs Ambient Lighting

- Task lighting
  - Higher intensity
  - Local lighting
  - Optimized for acuity, task, duration, comfort
- Ambient lighting
  - Lower intensity
  - Broad area lighting
  - Optimized for safety, mood
- My focus is on task lighting



pt.slideshare.net

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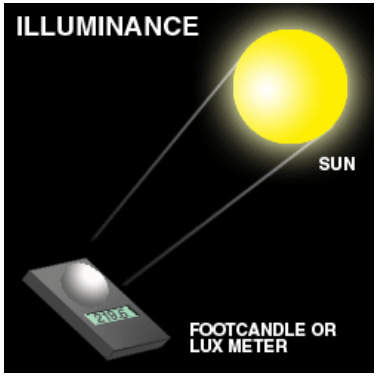
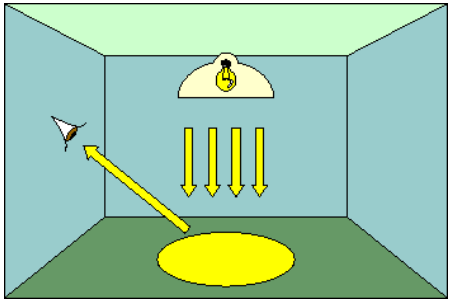
Illuminance vs. Luminance

- Illuminance: **light hitting the page**
  lux (lumens/m^2) or foot-candles;
  1 foot candle = 10 lux
  - Usually diminishes with distance and angle from source
  - Independent of surface properties (color, finish, texture)
- Luminance: **light coming from the page**
  (candelas per square meter, cd/m^2)
  - Depends on surface properties such as texture, reflectance.



www.klightlab.com



www.new-learn.info

Luminance and illuminance in vision testing

Luminance: Built-in light

Illuminance – Reflected light

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Relating
luminance and illuminance

- As a simple rule of thumb,
- For a reflective matte surface,
  1 candela/m^2 ≈ 3 lux (3 lumens/m^2)
- For example, a back-lit eye chart emits 200 cd/m^2.
  This is equivalent to the illuminance on a white matte eye chart in a 600 lux exam room.

=

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Common illuminance values

Starlight	.0001 lux
Full moon	.27 – 1 lux
General residential lighting	50 – 100 lux
Very dark overcast day	100 lux
Residential dining room	100 – 200 lux
Residential reading	200 – 500 lux
Classroom, bright lit exam room	500 – 1,000 lux
Overcast day	1,000 lux
Full daylight	10,000 – 100,000 lux

www.ltlmagazine.com

Source: Rea MS. *Lighting Handbook: Reference and Application.* NY: Illuminating Engineering Society of North America; 1993; Wikipedia

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Measurement of lighting

- Light meters measure illuminance in either
  - Lux, or
  - Footcandles
- Relatively inexpensive
  - ~ $30.00 and up

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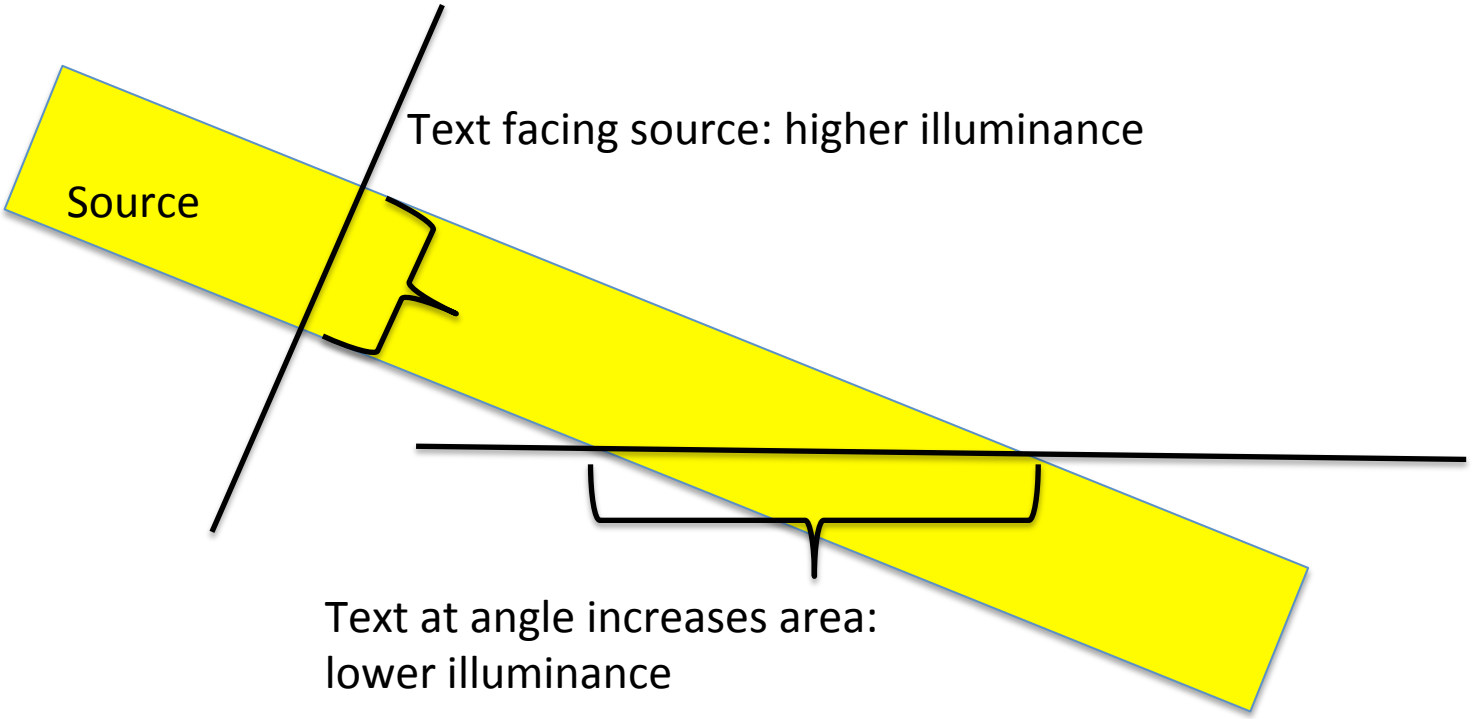
Illuminance and angle

- Illuminance depends on angle between light source and reflecting surface. The lower the angle the lower the illuminance.



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Key properties: Color

- Color arises from the mix of wavelengths in the source light
- Monochromatic light has one wavelength:
  - Green = ~527 nm
  - Red = ~630 nm
- Mixing colors creates hues

  (More on this later)

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Key properties: Contrast

- Contrast = difference between background and text
- 100% contrast is pure black on pure white
- Eye charts often have 80% contrast while many reading materials have low contrast
- Contrast is a property of the medium - lighting or filters do not change it.

The Daily

Martians invade earth

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Contrast

- Common definition is:

$$Contrast = \frac{R_{MAX} - R_{MIN}}{R_{MAX} + R_{MIN}}$$

  - Perfectly white page with black test has contrast of 1 or 100%
  - A newspaper might have dark grey print (75% reflection) on light grey paper (15%) yielding a contrast of 67%
- Lighting or filters do not change contrast!

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Key properties: Glare

- Unwanted light from window, lamp, reflections, or the page itself.
- Glare can be difficult to control when providing bright light.

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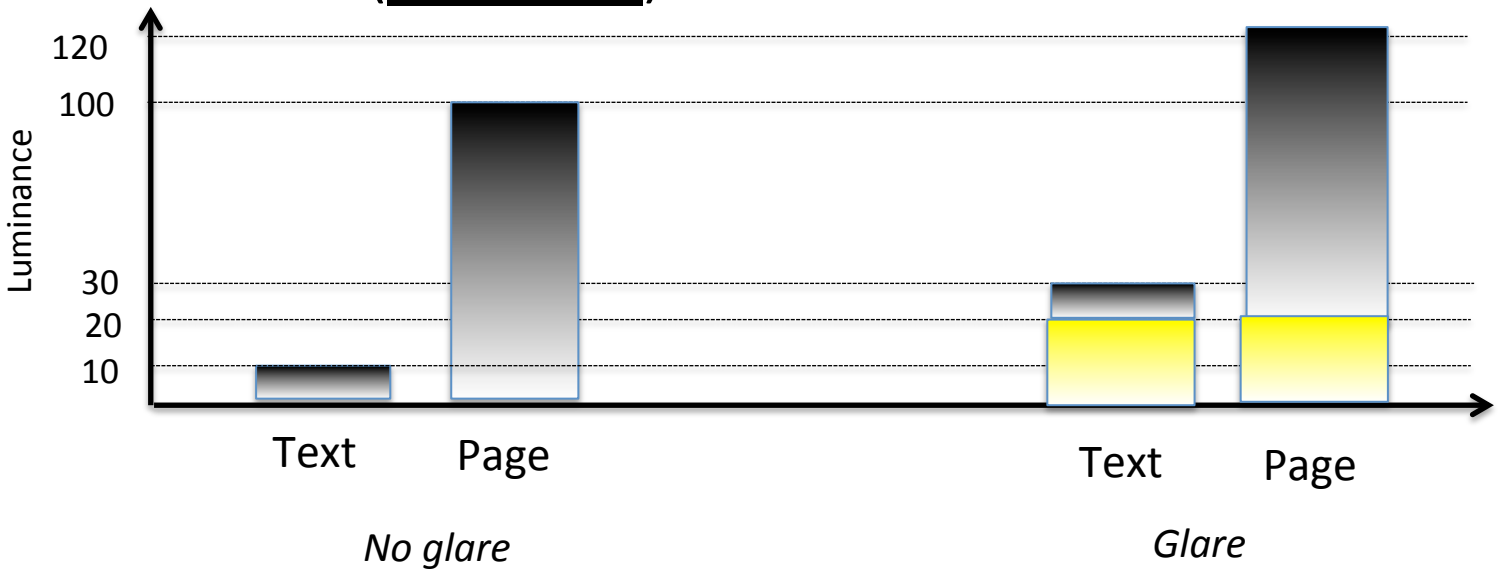
Glare: Reduces perceived contrast

- Lighting does not change actual contrast, but reduces retinal (perceived) contrast



Contrast =
(100–10) / (100+10)=82%

Contrast =
(120–30) / (120+30)=60%

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Glare: Example

Clock on night stand
without (clock face visible)

And with bright glare source
(clock face not visible)

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A way to reduce glare

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Brightness: Steven's Power Law

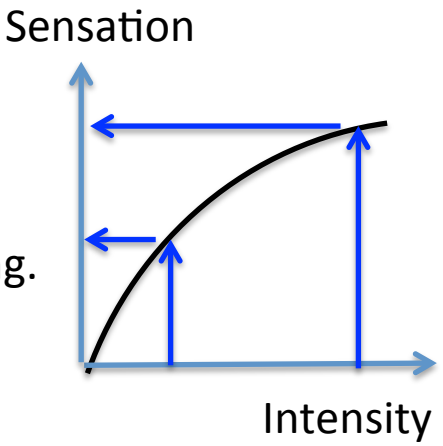
The eye's sensation of higher intensity decreases as the intensity increases.
Only large changes in brightness are effective.
This may increase glare unless lighting is carefully controlled.

Example:

3-way bulb with 50, 100 and 150 watts output.

The difference, 50 watts, is the same between each setting.

0 to 50 watts is more noticeable than 100 to 150 watts.



Schwartz, Visual Perception, 4th edition

Warm and cool white

“Warm” has more red

“Cool” has more blue

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Lights have a (non-intuitive) color temperature (º Kelvin)

- The higher the temperature the cooler the light color)

Warmer

Cooler

Temperature	Source
1,700 K	Match flame
1,850 K	Candle flame, sunset/sunrise
2,700–3,300 K	Incandescent lamps
3,000 K	Soft White compact fluorescent lamps
3,200 K	Studio lamps, photofloods, etc.
3,350 K	Studio "CP" light
4,100–4,150 K	Moonlight,[2] xenon arc lamp
5,000 K	Horizon daylight
5,000 K	tubular fluorescent lamps or Cool White/Daylight compact fluorescent
5,500–6,000 K	Vertical daylight, electronic flash
6,500 K	Daylight, overcast
5,500–10,500 K	LCD or CRT screen
15,000–27,000 K	Clear blue poleward sky

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AMD and more light

- Most normally sighted folk reach peak acuity at 500 lux (normal task lighting).**
- AMD patients may need >4X or 2000 lux to achieve peak acuity.
- Most prefer brighter light

** More about this later – lighting to maximize acuity and preferred lighting for reading are different.

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www.pinterest.com

WBRC Study

- Designed to compare visual acuity (high and low contrast) for normals and low vision patients
- Compared acuity measured in the clinic with that obtained using the LuxIQ
  - Subjects set:
    - Brightness
    - Color temperature
- Counterbalanced order of presentation

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WBRC Study participants

	Controls (N = 10)	Subjects N = 30)
Mean Age	55.5 yrs. (40 - 68)	70.7 yrs. (51-90) *
Working Distance	44.7 in. (32-56 cm)	26.3 in. (12-45 cm) **

- Controls significantly younger than subjects
- Controls used significantly greater working distances
- Subjects had variety of pathologies
  - AMD = 8
  - Glaucoma = 8
  - Other TBI (hemianopia), NAION, diabetic retinopathy, trauma/TBI, interstitial keratitis, CRAO, and macular edema
- Controls preferred greater brightness than subjects
- Subjects used best near correction for all conditions

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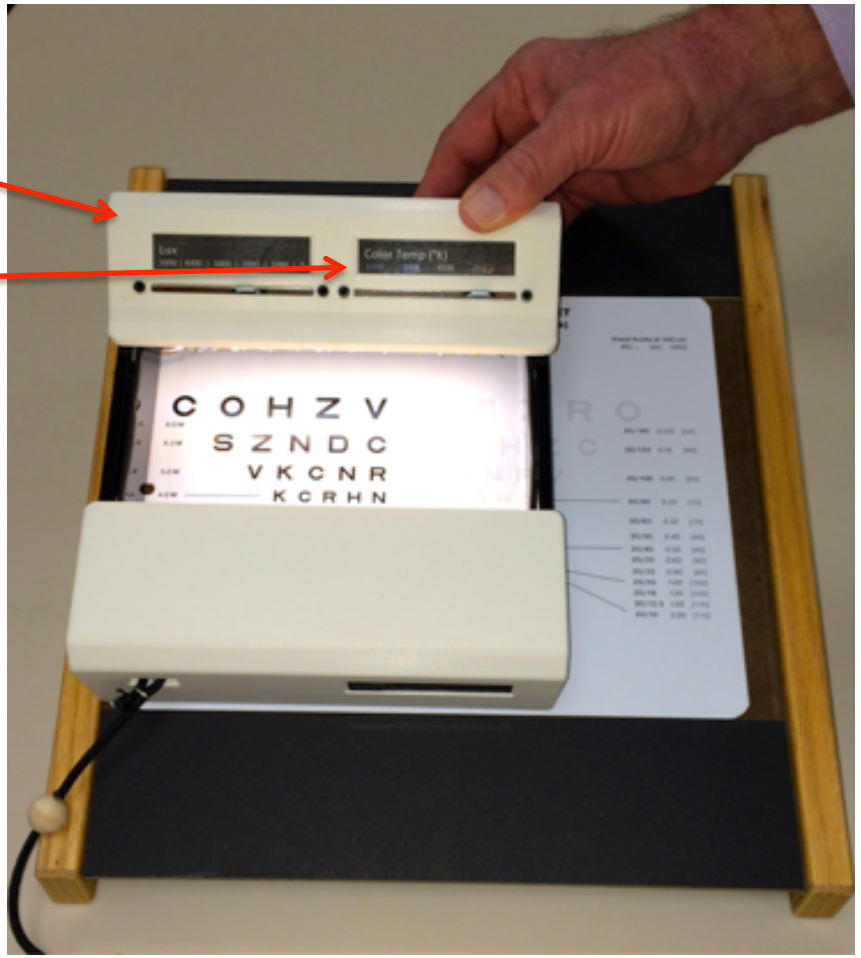
Lighting measurement tools: LuxIQ

- Left slider controls brightness
  - 0 to 5,000 lux
- Right slider controls color temperature
  - 2,700 to 6,300 ^{o}K
- Sliders move left to right to increase brightness/color temperature
- Readings from scales above sliders
- Colenbrander high/low contrast near acuity chart
- Recorded number of letters read



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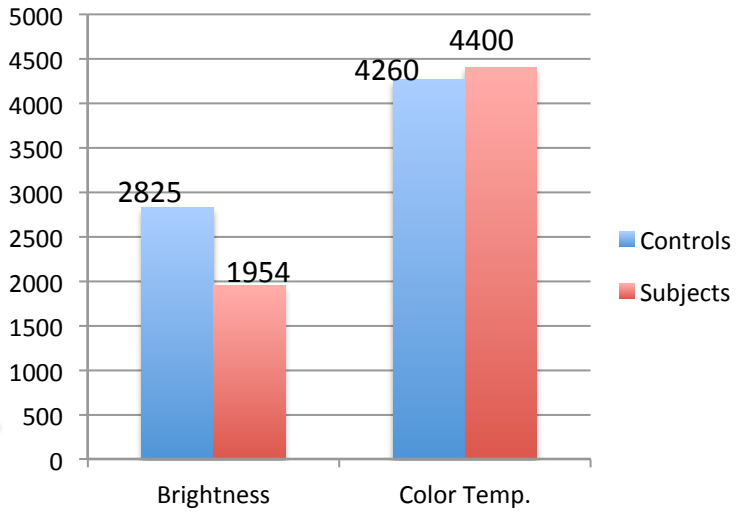
Controlled study of brightness and color temperature

- Controls preferred significantly brighter light
  - Controls: 500 – 5000 lux
  - Subjects: 700 – 5000 lux
- No significant difference between normal and control populations on color temp.
  - Controls: 2700 – 5500 ºK
  - Subjects: 2700 – 6500 ºK



500 lux = value where normally sighted reach asymptote for visual acuity

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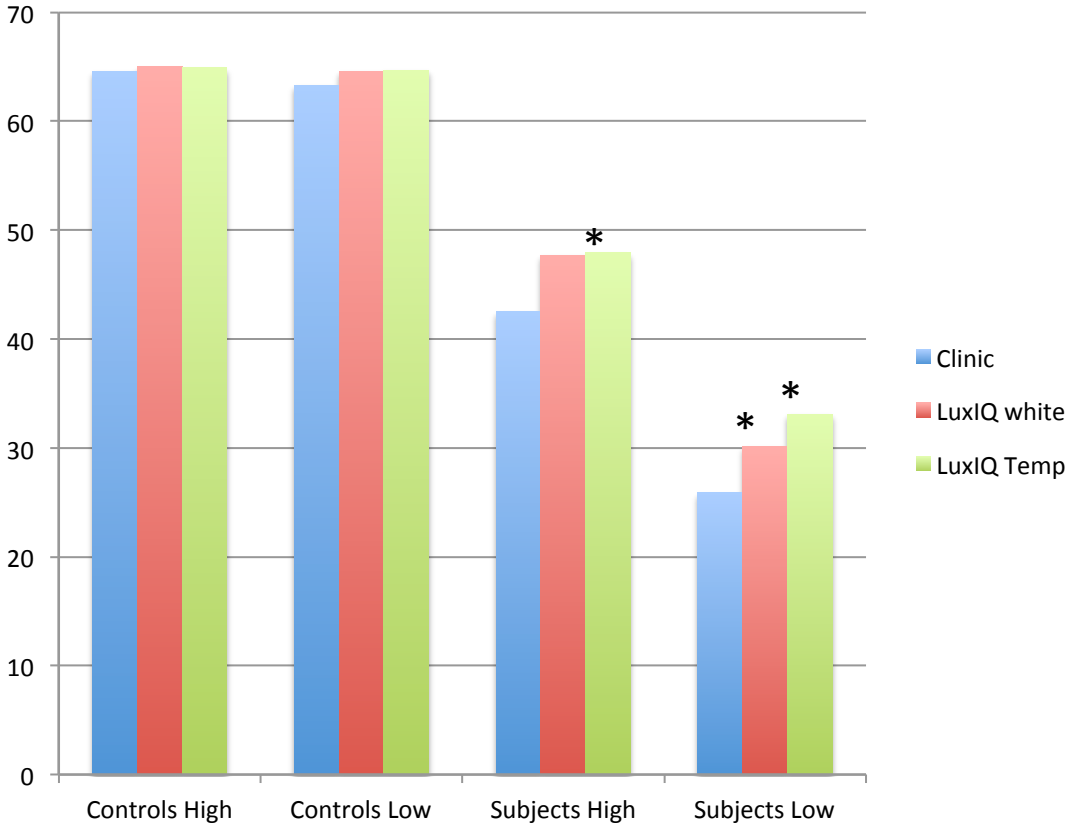
Number of letters read

- Maximum letters = 65
- No significant change for controls
- Compared to clinic illumination subjects read significantly greater number of characters on both high and low contrast charts
- Gain varied by subject from no additional letters to over 2 lines



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Study Conclusions

- Both controls and subjects preferred bright light (controls significantly more)
- Controls and subjects very similar in preferred color temperature
- Brightness and color temperature significantly improved number of letters read on high contrast for subjects but not controls
- Brightness and color temperature each significantly improved number of letters read on low contrast for subjects but not controls
- Optimized lighting enhanced effectiveness of low vision prescription
- Low vision individuals using optimized lighting read smaller print; **optimized lighting = magnification**

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Caveats

- Not all subjects preferred or benefited from brighter light
  - Even among AMD patients who are thought to need more light
- Preference for lighting is individual for both controls and low vision subjects
- Individual measurement and prescription of lighting should improve low vision individual's performance on near tasks

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Related studies

- Rotruck and Fletcher (ARVO 2015)
  - POAG patients prefer significantly less light than AMD patients
    - POAG 2,345 lux (±922); AMD 4,289 lux (±713)
  - Optimum lighting significantly improves acuity

Hi contrast	1.8 M	1.2 M
Low contrast	6.6 M	5.2 M
	Room (500 lux)	Optimum

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Prescribing lighting

- Current standard is trial and error lacking systematic, calibrated basis

Swapping bulbs

…or lamps

- LuxIQ offers a calibrated option
  - It has been shown to improve acuity and may improve visual comfort for low vision readers.

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Next steps

- I'm a card carrying researcher so of course I'm going to tell you more research is needed
  - Does optimum lighting improve reading duration?
  - Does improvement translate to other tasks?
  - Studies done are with adults, does the benefit translate to children?
    - Study with children with CVI starting up at California School for the Blind (Marasch, Lueck, & Goodrich)
  - LuxIQ2 may provide calibrated tool for prescribing tints/filters?

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Research Findings References (available at www.jasperridge.net)

- AAO 2013
  - Quantifying Patient Lighting Needs to Improve Low Vision Clinical Practice and Patient Performance - *Gregory L. Goodrich, Shanida Ingalla, Megan Dolkas*
- Envision 2014
  - Is Low Vision Lighting Coming of Age - *Gregory L. Goodrich, Donald Fletcher, Karen Kendrick, Faydim Rassamdana*
  - Measuring and prescribing preferred light intensity and color - *Peter Borden, Michele Klein*
- ARVO 2015
  - Patients with AMD and POAG may require different lighting to maximize visual acuity - *Jill Rotruck, Don Fletcher; Laura Walker*
  - Functional Impact of Task Lighting on Reading with Low Vision - *Tony A. Succar, Laura Walker, Karen Kendrick, Andra Mies, Donald C. Fletcher*

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Questions?

Thank you!

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